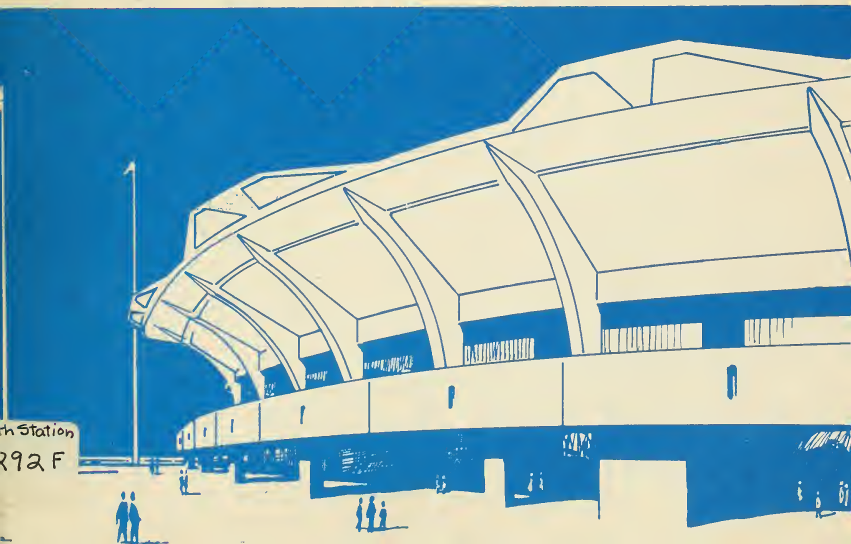
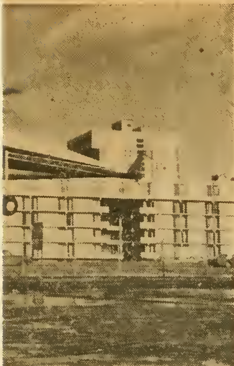
FEASIBILITY STUDY of a SPORTS STADIUM for GREATER BOSTON

Report of:

BRAIN, Inc.

Appendices





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DPW Asks Bid On Inner Belt

The Dept. of Public Works has advertised for bids for the construction of the interchange section of the Boston Inner Belt and Instate Rte. 93 in Somerville.

Comm. Edward J. Ribbs said bids for the steel viaduct sructure, estimated to cost more than $10 million, will be opened at the dpw on July 15. Plans call for the construction only for the ramps to interchange with the Boston section of the Inner Belt, now inder construction between the Central Artery at City Sq. in Charlestown and Somerville.

The construction contract will call for a completion date of mid-1972, Ribbs said, to coincide with plans for the completion of two sections of I93 in Medford and Somerville to be advertised later this year.

The work will be coor- nated with plans of the B- ton and Maine RR to re- cate tracks, and with t MBTA to relocate its No Station to Sullivan Squa line under or next to the e vated highway.

Traffic Studied At JFK Site

A Brookline selectm. yesterday asked that a bro: traffic study be undertak in the area of the birthpla of John F. Kennedy, whi was dedicated as a nation historic site last Thursday

It became evident that th town would face some head aches from vehicular traff as 2000 persons jammed nar row Beals st. last week t attend the ceremonies.

May 19, 1969

TO: Tony DiSarcina — will go
Don McInnes "
Ralph Partan — pass 2B

FROM: Larry Kirsch

SUBJECT: Stadium

If any of you would like to attend the M.I.T. review, would you please let me know at your earliest convenience.

LK/mh

Attachment: Letter of 5/9/69 from Professor Robert V. Whitman to Mr. Champion (copy of)

Champion

See "SIGMA" and "BRAIN" reports in STADIUM-Reports file

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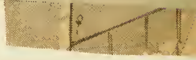

OFFICE OF THE DIRECTOR

TO:

☐ SIMONIAN Executive Director	☐ BERRY Proj. Dir., Campus High, Wash. Park
☐ DOLAN Admin. Dev./Legal Support Services	☐ LOCKHART Proj. Dir., South Cove
☐ DROUGHT Admin. Staff Services	☐ LOVERUD Proj. Dir., Waterfront
☐ HILGENHURST Admin. Planning/Urban Des./Advanced Projs.	☐ NOONAN Proj. Dir., Charlestown
☐ SMART Admin. Commun. Organ./Soc. Services	☐ SMART Proj. Dir., South End
☐ CONLEY General Counsel	☐ WENNIGER Proj. Dir., Fenway, North Harvard
☐ MC MORROW Educational Programs	☐ MC INNES Director, Non-Res. Dev.
☐ PAULSEN Exec. Officer, C.A.C.	☐ ZEIGLER Director, Planning Dept.
☐ WYLIE Special Counsel	☐ DIAMOND Director, Urban Design Dept.
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☐ FRIEDMAN Public Inform. Officer	☐ O'NEILL Chief, Bus. Reloc. Section
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☐ WEINER Asst. Operations/Pub. Services	☐ MURPHY Chief, Transportation Planning
☐ JOHNSON Asst. Staff Services	☐ MC GRATH Transportation Liaison
☐ MC GOVERN Director, Real Estate	☐ . . . .

- ☐ Please Handle
- ☑ Prepare Reply for My Signature
- ☐ Prepare Reply for Mayor's Signature
- ☐ Immediate Action
- ☐ Acknowledge with Thanks
- ☐ Your Written Comments
- ☐ Please See Me On This
- ☐ For Your Information
- ☐ Xerox . . . . Copies

ORIGINAL CORRESPONDENCE TO BE RETURNED IN ALL CASES.

COMMENTS:

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HALE CHAMPION
DIRECTOR

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DEPARTMENT OF CIVIL ENGINEERING
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CAMBRIDGE, MASSACHUSETTS 02139

May 9, 1969

RECEIVED
MAY 15 1969
Boston Redevelopment Authority
Office of Development Administrator

Mr. Hale Champion
Boston Redevelopment Authority
City Hall Annex
Boston, Massachusetts

Dear Mr. Champion:

One of the basic courses in our curriculum is a Senior projects course called simply "Civil Engineering." In this class the students are asked to study and if possible solve a comprehensive, real-world engineering problem. The course is intended to be the capstone of the undergraduate program in civil engineering and is representative of the modern trend in engineering education.

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The project will be culminated by an oral presentation on May 29. On this occasion each group will present and defend its proposed design and economic analysis. We are inviting prominent community leaders from the area to attend, both because we believe such leaders are interested in education and because we wish to add realism to the student presentations. The visitors will be asked to grade the two groups and thus assist the faculty in its evaluation of the performance.

I would like to extend a personal invitation to you. I am sure that you will find it to be a very interesting experience and rewarding from your viewpoint.

The presentation will be held at 2 P.M. on Thursday, May 29 in Kresge Little Theater which is in Kresge Auditorium (the large spherical shaped building with a sloping roof on your left as you come from Boston on Massachusetts Avenue.) Parking will be available at West Garage on Vassar Street (your first left after passing Kresge.)

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Sincerely yours,

Robert V. Whitman

Robert V. Whitman
Professor of Civil
Engineering

RVW:kjn

Larry Kirsch
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May 19, 1969
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Don McInnes
Ralph Partan

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THE DIRECTOR

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Robert V. Whitman
Professor of Civil
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RVW:kjn

FEASIBILITY STUDY OF A SPORTS STADIUM

FOR GREATER BOSTON

APPENDICES TO THE STUDY

BRAIN Inc.

Basic Research and Innovation, Inc.

May, 1969

APPENDICES

A)	Parking Analysis	Joe Levitch
B)	Traffic Analysis	Joe Levitch
C)	Pedestrian Analysis	Joe Levitch, Steve Passage
D)	Site Planning	Steve Passage
E)	Foundation Analysis	Greg Madera, (Chris Ryan assisting)
F)	Stadium Configuration	Robert Trapp
G)	Structural Analysis	Peter Busch, Fred Nassimi, Robert Trapp
H)	Stadium Roof	Robert Trapp
I)	Cost and Revenue Estimates	Bruce Glabe, James Marshal
J)	Financial Performance and Economic Evaluation	Bruce Glabe

APPENDIX A

PARKING ANALYSIS

Parking Availability at the South Station Site:

Primary Area

a) is the area within "reasonable" walking distance of the Stadium - less than ½ mile from site.

b) is defined as the area bounded by Kneeland/Stuart Street, East Berkeley Street, and the present South Bay and Fort Point Channel.

c) contains 2,900 off-street parking spaces. For analytic purposes these may be considered 90 per cent available on nights, weekends, and holidays, and 30 per cent available otherwise.

d) contains the proposed 5,400 space South Station Garage. For analytic purposes, this garage may be considered 90 per cent available on nights, weekends, and holidays, and 40 per cent available otherwise.

Secondary Area

a) is an area immediately adjacent to the perimeter of the primary parking area within an acceptable walking distance from the stadium site.

b) contains 2,750 off-street parking spaces. For analytic purposes these may be considered 90 per cent available on nights, weekends, and holidays and 30 per cent available otherwise.

Preliminary Analysis of Parking Availability at the South Station Site

A preliminary step in the parking analysis is the computation of the number of spaces required for various stadium events. Those events with which we are most concerned are baseball and football contests. The expected number of persons per vehicle, based on figures from the Highway Capacity Manual (1965) of the Highway Research Board, to be used in this analysis is 2.5 persons per car.

According to statistics of the Transportation Planning Department of the BRA, surveys taken in the period from 1961-63 of various events at Fenway Park indicate that approximately 20% of the spectators use public transportation. This percentage seems lower than that which could be achievable with improvements in MBTA service, but it is the percentage that shall be used for the purposes of this analysis.

Combining these facts with various levels of expected attendance, the parking requirements in Table A-1 have been established. This table translates the anticipated attendance into parking requirements based on the 20 per cent usage of public transit, a 5,400 space garage, and no parking provisions on the site itself.

An analysis of the schedule of games for the Boston Red Sox indicates that approximately 75 per cent of the games at home are played on weekends, nights, or holidays. The remaining 25 per cent of the home contests are scheduled for weekday afternoons. the breakdown is as follows:

BASEBALL:

Weekday Afternoons	19 games
Weekday Evenings	34 games
Weekends and Holidays	25 games

Expected Attendance	Parking Spaces Needed	Existing Supply of Parking Primary		Secondary	Total Supply	Surplus (+) or Deficit (-)
Less Than 25,000	0 to 7,999	7475	Nights Weekends Holidays	2475	9950	+9950 to +1950
		3050	Other	825	3875	+3875 to -4125
25,000 to 37,000	8,000 to 11,999	7475	Nights Weekend Holiday	2475	9950	+1950 to -2050
		3050	Other	825	3875	-4125 to -8125
37,000 to 45,000	12,000 to 14,399	7475	Night Weekend Holiday	2475	9950	-2050 to -4450
		3050	Other	825	3875	-8125 to -10,525
45,000 to 60,000	14,400 to 19,200	7475	Night Weekend Holiday	2475	9950	-4450 to -9250
		3050	Other	825	3875	-10,525 to -15,325

Table A-1

SURVEY OF AVAILABLE PARKING
IN SOUTH STATION AREA

The Boston Partiots normally play one-half of their scheduled games at home, and all are played on weekends or holidays. The breakdown is as follows:

FOOTBALL:

Weekends and Holidays	7 games
Weekday Afternoons	———
Weekday Evenings	———

Looking at the table of parking requirements, it is now necessary to analyze the deficiencies existing in the supply of parking spaces. The configuration for baseball should have a maximum seating capacity of 45,000 spectators. This indicates a maximum deficiency of 4,500 spaces on weekends and evenings and 10,500 on weekdays. For football, a configuration with a seating capacity of 60,000 is desirable. Thus, football games would require 9,250 additional parking spaces under maximum conditions.

The above described conditions, involving maximum addendance rates, cannot possibly be accommodated through provision of additional parking of the magnitude indicated. It must be assumed instead that with parking only sufficient to handle events of normal attendance, the public attending major events will shift to other means of transportation or accept walking distances greater than those considered acceptable under normal conditions. This assumption seems necessary to the consideration of a major stadium located so close to the central business area. It is hoped that on holidays in particular, and possibly weekends, the curb areas in the primary parking zone could be made available for some of the overflow. Such use of the street system should be permissible as a general rule.

It is also to be noted that the analysis does not account for any service to the stadium which might, and undoubtedly would, be provided by special busses. For major events, such as home football games and weekend baseball games, as many as 100 busses could be expected. This would cut the parking needs by 1,800 to 2,000 spaces. Space for this number of busses must be provided in the layout of the stadium area.

It is further noted that a certain percentage of spectators for weekday baseball games would be workers from the central business district whose automobiles were already parked. The reduction in parking requirements thus produced may be in the range of 2,000 to 3,000 spaces, depending on the attendance level of the event.

On dates of less than maximum attendance, parking requirements would be somewhat reduced. It will be noted that the total variation in attendance and use conditions depending on the day of the week and the time of day are such that over-all variation in the parking situation ranges from a surplus of 2,000 spaces on nights and weekends for average baseball attendances to a deficiency of 6,000 spaces for weekend football games and weekday baseball games of average attendance. This is the typical condition depending on crowd size to be handled. It suggests that there may be many days in which available space is not utilized and some when there is not enough. The number of additional spaces required for the majority of events to be held in the stadium is in the vicinity of 6,000.

From site and area considerations there is a possibility of permitting inclusion of 3,000 spaces south of the site to supplement the existing supply. This is about midway in the range of normal needs. This on-site area should also be adequate for the parking of busses at major events. This reduces the average deficiency to approximately 3,000 spaces, which can almost definitely be handled by additional parking development proposed within the primary parking zone.

The foundation design allows the inclusion of a parking facility under that part of the stadium built over the Fort Point Channel. The number of spaces that can be provided is approximately 600. It is suggested that these spaced should not be available to the public; rather, they should be used for team members and their families, team officials, public officials, and agents of the press, radio, and television. The remaining spaces should be rented on a seasonal basis (first come - first serve) to holders of season tickets.

Of some importance and consideration to the size of this on-site facility is the surplus created by its presence for events of low attendance. This lot would be used in lieu of existing parking areas in the secondary zone, which is at a less acceptable walking distance from the stadium. For this reason there would be no events in which it was not at least partially used, and its total use would depend on the decision of individual drivers between spaces in this facility and those in the garage or primary area.

Recommendations on Size and Ramp Configuration of the Parking Garage

Proposals for ramp configuration made by the Massachusetts Port Authority are entirely sufficient for the pattern of usage related to the stadium. They will be briefly stated here as an integral part of this analysis.

The concept of the parking garage would be to provide direct access to the Massachusetts Turnpike and the Fitzgerald expressway. Vehicles from these roadways would enter from the south end of the garage, as would vehicles from Dorchester Avenue, by means of elevated ramps. Vehicles from all other surface streets would enter the facility from both sides near the north end. Exits from the garage would be at the same points, with vehicles proceeding along ramps which either connect to surface streets or the Turnpike or Expressway. Vertical movements would be contained within the structure. For the general garage concept and proposed access system, see Figures A-2 and A-3.

Based on proposals for improvements to be made in Atlantic and Dorchester Avenues, the Port Authority's analysis indicated that these and other adjacent streets would be operating at about 90 per cent of their capacity. The ramps, however, unlike the surface streets, would be operating at only 45-55 per cent of their capacity. Implications of these figures are that a garage capacity of greater than approximately 5,000 vehicles would cause critical congestion problems on the surface street network, especially when consideration is made of the large number of vehicles parked in either areas adjecent to the stadium site.

(underlined figures give capacities of lots and garages)
(circled figures give codes of ownership available from BRA)

FIGURE A-1
AVAILABILITY OF PARKING IN THE
SOUTH STATION VICINITY

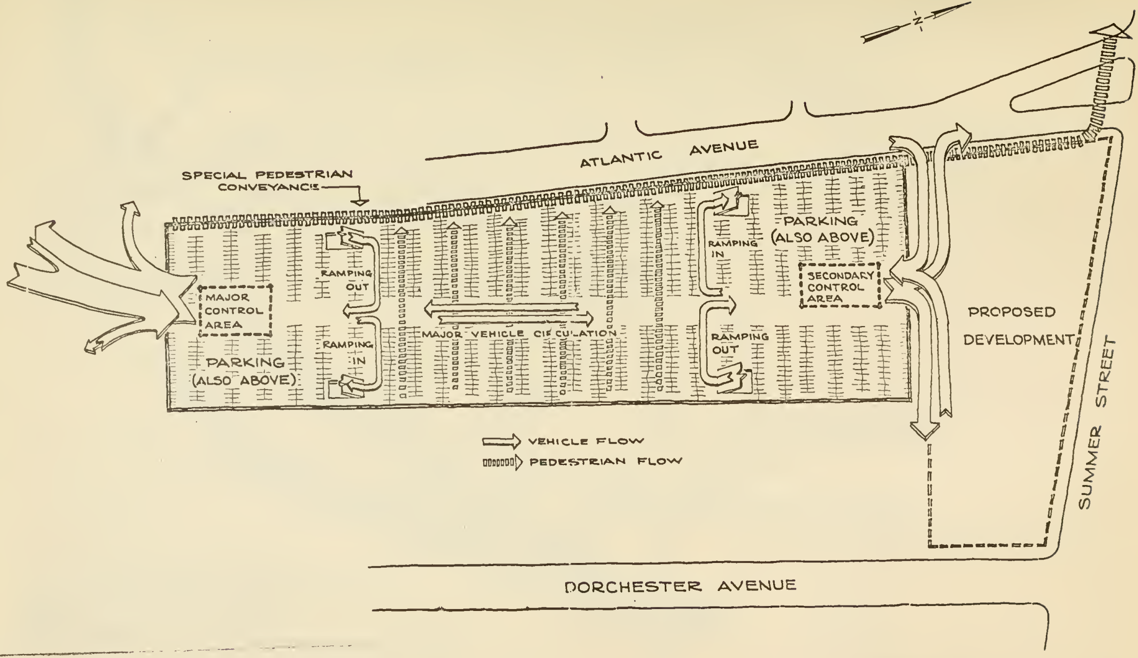


FIGURE A-2

GENERAL CONCEPT OF THE SOUTH STATION PARKING GARAGE
AS PROPOSED BY THE MASSACHUSETTS PORT AUTHORITY

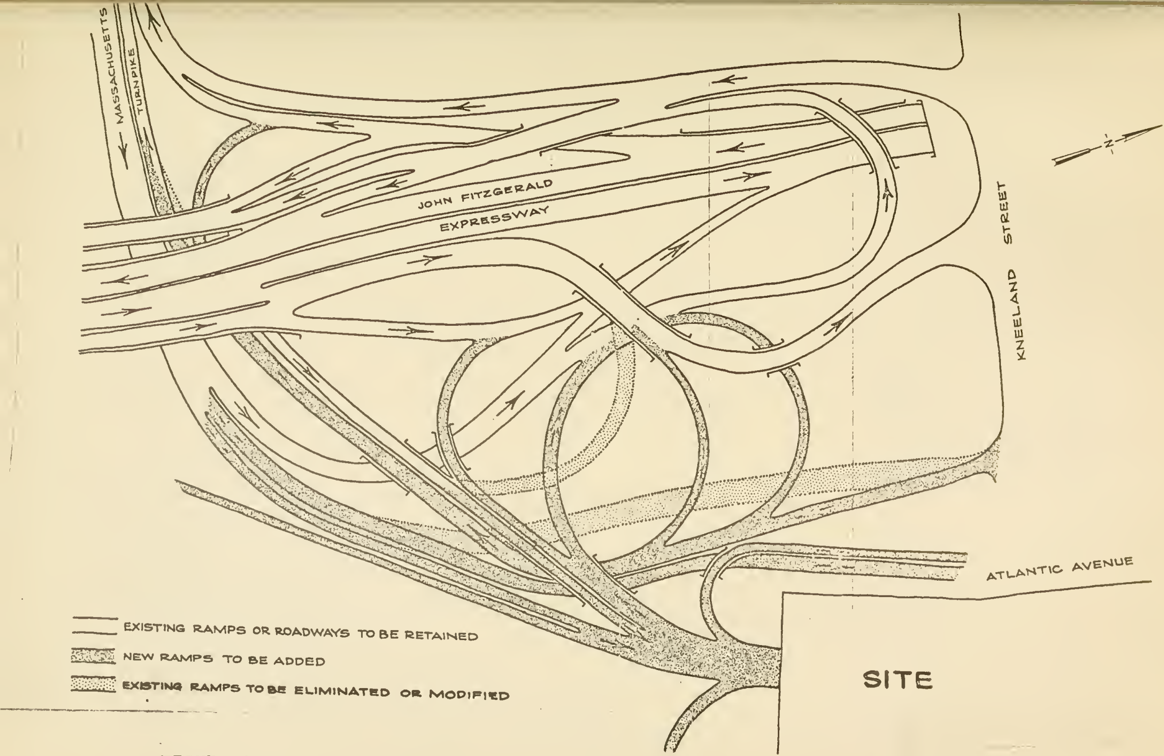


FIGURE A-3

GENERAL CONCEPT OF THE ACCESS SYSTEM OF THE GARAGE
AS PROPOSED BY THE MASSACHUSETTS PORT AUTHORITY

APPENDIX B

TRAFFIC ANALYSIS

Vehicular Circulation Considerations

Having established parking needs and a reasonable magnitude of parking availability which might be provided, it is necessary to consider the traffic implications of the stadium. Most important is to evaluate the flow generated by stadium users additive to the normal flow found on the surrounding street and expressway network and to determine what traffic handling difficulties may occur.

The major street system which will play a role in handling stadium site parking is listed as follows:

Central Artery
S.E. Expressway and Inner Belt
Mass. Turnpike Extension
Dorchester Avenue
Kneeland Street
Essex Street

There are also several Turnpike frontage roads and a proposed third harbor crossing that can be utilized for vehicular access. There is a total of 10-14 lanes of expressway and 12 lanes of arterial street.

An analysis of the direction of approach to the South Station site area conducted for the Massachusetts Port Authority revealed the following figures:

NORTH	31%
EAST	12%
SOUTH	29%
SOUTHWEST	12%
WEST	16%

Of these percentages it is estimated that approximately 42% of potential users would travel via the expressway and turnpike system. This is shown on Figure B-1.

The major approach flow directions of stadium bound traffic have thus been determined. Based on general considerations of the over-all street and expressway system of the Boston area and the likely approach direction of spectators to the stadium site, the following levels of movement have been estimated for a weekend function generating 14,000 vehicles. This would accound for maximum baseball attendance of 45,000 spectators (32,000 from private autos, 4000 from special busses, and 9000 from public transit).

FROM THE	NORTH	4350 cars
	EAST	1650 cars
	SOUTH	4000 cars
	SOUTHWEST	1650 cars
	WEST	2350 cars
	TOTAL...	14,000

The major parking facility location areas are restated here.

PRIMARY AREA	2900 spaces
GARAGE	5400 spaces
SECONDARY AREA	2700 spaces
ON-SITE	3000 spaces
TOTAL...	14,000

The approach distribution to these various parking areas can now be determined. Because of the nature of the expressway and turnpike extension and their connections to the garage most traffic from the west will use the South Station garage. Traffic from the south and southwest will divide between the garage, the on-site parking area, and lots in the primary and secondary areas. Traffic from the east can be expected to use the on-site parking, and those approaching from the north can be expected to divide between the garage and areas in the primary and secondary zones.

Evaluating the expected traffic flows leads to the conclusion that the exit period will be the most difficult to handle and therefore the period that the system must be devised to accommodate. The primary objective is to discharge all the parking areas within a thirty minute exit time. For this purpose, it is necessary to generate a vehicle per hour flow rate of double the number of vehicles to be handled.

Therefore, we must consider the following flow rates as crucial in achieving the desired objectives:

NORTHBOUND	8700	vehicles/hour
EAST	3300	vehicles/hour
SOUTH	8000	vehicles/hour
SOUTHWEST	3300	vehicles/hour
WEST	4700	vehicles/hour
	28,000	

Referring to the diagram, "Direction of Approach," the traffic will be divided as follows:

SOUTHBOUND, X-WAY / S-WEST BOUND, X-WAY	29%	8000 veh/hr.
SOUTHBOUND, SURFACE	13%	4000
NORTHBOUND, X-WAY	14%	4000
NORTHBOUND, SURFACE	17%	4700
WESTBOUND, SURFACE	16%	4000
EASTBOUND, SURFACE	12%	3300
		28,000

It is now necessary to determine the effect of this increase in the number of vehicles on the circulation system. Adding traffic counts from the Department of Public Works for the Southeast Expressway to stadium traffic gives these results for weekend, holiday, and evening conditions:

X-WAY, SOUTHBOUND	stadium	8000
	general	3500
		11,500 veh/hr.

X-WAY, NORTHBOUND	stadium	4000
	general	3000
		7000 veh/hr.

Using criteria established by the Highway Research Board presented in Table B-2, we can better characterize the situation. In the southbound direction, traffic flow will be at level F, a forced-flow condition in which the expressway acts as a storage for vehicles. To establish stable flow conditions in the upper speed range, it would be necessary to provide an additional six southbound lanes. For unstable flow with speeds in the range of 30 m.p.h., three additional lanes would be sufficient. These figures are only estimates, and a detailed analysis would require a study of each potential bottleneck or restriction within the roadway section. These figures, however, serve to point out the severity of the problem.

In the northbound direction level of service will again be level F. A third harbor crossing with three northbound lanes connecting to the northern expressways would be of great benefit to the circulation problem. Assuming a split between the new crossing and the existing expressway of 40-60, the volumes will be:

HARBOR CROSSING	2800 veh/hr.
X-WAY	4200 veh/hr.

For these volumes, the harbor crossing will operate at level B, stable flow with speeds in the range of 55 m.p.h., and the expressway will operate at level C, stable flow with speeds around 50 m.p.h. Again, specific characteristics of the system will affect these service levels, but these figures aid in defining the problem more clearly.

In analyzing the flow on the downtown surface street system, a different approach must be taken. The HRB has not seen fit to provide procedures for determining levels of services for downtown streets. Using a rudimentary scale which does not relate to volumes but to overall travel speeds, level of service F with forced flow and stop-and-go traffic would adequately characterize the operation of surface streets in the downtown area.

If a program can be undertaken to increase transit patronage, it may be possible to improve the circulation conditions. Considering southbound traffic on the expressway as the most crucial, let us determine the required transit patronage to produce acceptable conditions on the expressway. For level of service E, unstable flow with speeds of 30 m.p.h., southbound stadium traffic would have to be reduced to 2500 cars. This excludes 5500 automobiles, or almost 14,000 extra persons per hour, to be served by rapid transit and trains. It should be pointed out that even if service for these patrons can be provided, the surface street flow has not been improved, and this is a major congestion problem resulting from events in the stadium. Overall transit patronage would have to be improved - doubling patronage to 40% would reduce the number of autos on the downtown streets to approximately 10,000 vehicles per hour, producing a somewhat more acceptable situation. With the recommended parking on-site, it would also completely eliminate any deficiency in parking availability.

In considering conditions during the week, it has been assumed that a large number of spectators would come from the CBD. To produce the most desirable results, let us say that this figure may be as high as 3000. Transit may account for 9000 spectators (20%) and another thousand may use special busses. The number of automobiles that will be added to the circulation system and their distribution is as follows:

SOUTHBOUND,	X-WAY	29%	8000
NORTHBOUND,	X-WAY	14%	4000
S-BOUND,	SURFACE	13	4000
N-BOUND,	SURFACE	17	4700
W-BOUND,	SURFACE	16	4000
E-BOUND,	SURFACE	12	3300
		TOTAL:	28,000 veh/hr.

Adding expressway counts to these figures gives these results:

S-BOUND, X-WAY	stadium	8000
	general	3500
		11,500
N-BOUND, X-WAY	stadium	4000
	general	6000
		10,000

Circulation in both directions would be at Level F. Northbound, the construction of the third harbor crossing and the assumed traffic split would result in volumes of 5600 veh/hr. on the expressway and 3700 veh/hr. on the harbor crossing. Thus, conditions of stable flow with speeds of 50 m.p.h. would be found on the harbor crossing and conditions of unstable flow with speeds around 30 m.p.h. would be found on the expressway. Southbound, the addition of two lanes would be required to produce unstable flow and five lanes to produce stable flow. To improve southbound circulation to the least acceptable level with no improvements, it would be necessary to increase transit patronage southbound by at least 12,000 persons. In considering the effect on circulation on downtown surface streets, an

additional 16,000 vehicles would enter the system under rush hour conditions (assuming 20% transit patronage).

Considering an increase in the level of transit patronage to 40%, more desirable conditions could be produced. This would reduce the total number of automobiles to 9000, which is much more compatible with the number of parking spaces available. It would also produce the following results on vehicular circulation (assuming the stadium is to be emptied within 30 minutes):

S-BOUND, X-WAY	29%	5200	
		general	3500
			8700
N-BOUND, X-WAY	14%	2500	
		general	6000
			8500
SURFACE STS.	57%	10,300	
	TOTAL:	18.000	

This reduces the congestion in the circulation system but does not eliminate the problem. Additional southbound capacity must be provided even with this increased use of mass transit. Service on downtown streets will still be at an undesirable level, with forced flow and stop-and-go conditions prevailing.

A similar analysis can be carried out for games of average attendance - 30,000 spectators. Conditions in this situation are much more tolerable. Only one extra freeway lane would be required in the southbound direction; the need for this could be eliminated by an increase of 3500 transit passengers southbound. Northbound traffic would be free-flowing, and congestion on downtown surface streets would not be as severe. The complete set of results, along with their expected probability of occurrence, is presented in Table B-1.

When considering the problem of circulation after football games, the circumstances are little changed from those of weekend baseball games. The added capacity is 7000 spectators, of which about 2500 will use public transit or special busses. An extra 1800 automobiles will have to be handled as follows:

X-WAY-S	29%	500
X-WAY-N	14%	250
SURFACE	57%	1050
	TOTAL	1800

Maximum attendance levels can be expected for all home football games, so traffic conditions associated with football games will be almost exactly similar to those of weekend baseball games. These results are also summarized in Table B-1.

The situation for vehicular circulation is not promising at all. Parts of the roadway network cannot handle the number of automobiles, and the tremendous increases in transit patronage required to free the roadways in equally unrealistic. If a stadium is to be located on this site, certain improvements must be made. The third harbor crossing and additional expressway lanes are necessary. Improvements in the circulation pattern and signalization on surface streets in the adjacent area is also required. An increase in the use of mass transit, trains, and special busses is another essential that people must be willing to accept. Innovation can be undertaken to eliminate the interaction of stadium users and CBD workers - changes in scheduling, promotion of dining or shopping in the CBD following games, and other methods to separate the vehicular demand on the roadways must be initiated. Massive problems of vehicular movement are to be expected with a stadium located in such close proximity to the central business

district, but many of them may be overcome through advance planning and timely improvements.

			BASEBALL								FOOTBALL	
			WEEKENDS, HOLIDAYS AND EVENINGS				WEEKDAYS				SUNDAYS	
		ATTENDANCE	30,000		45,000		30,000		45,000		53,000	
		PROB. OF ATTENDANCE	47%		40%		10%		3%		100%	
			Veh/hr.		Veh/hr.		Veh/hr.		Veh/hr.		Veh/hr.	
TRANSIT PATRONAGE	20%	X-WAY, NORTH*	3,300	B	4,200	C	5,100	D	6,000	E	4,350	C
		HARBOR CROSS*	2,200	A	2,800	B	3,400	B	4,000	C	3,000	B
		X-WAY SOUTH*	8,700	F	11,500	F	8,700	F	11,500	F	12,000	F
		SURFACE STS.**	10,300	F	16,000	F	10,300	F	16,000	F	17,000	F
	40%	X-WAY, NORTH*	2,900	B	3,300	B	4,700	C	5,100	D	3,450	B
		HARBOR CROSS*	1,900	A	2,200	A	3,100	B	3,400	B	2,300	A
		X-WAY, SOUTH*	7,300	F	8,700	F	7,300	F	8,700	F	9,200	F
		SURFACE STS.**	7,400	F	10,300	F	7,400	F	10,300	F	11,300	F

* includes all traffic
** only stadium traffic

Table B-1

VEHICLES PER HOUR ON CIRCULATION SYSTEM

LEVEL OF SERVICE	DESCRIPTION	OPERATING SPEED (MPH)	SERVICE VOLUME (VEH/HR)
A	Free flow	560	2400
B	Stable flow	555	3500
C	Stable flow	550	4800
D	Approaching Unstable Flow	540	5400
E	Unstable flow	30-35	6000
F	Forced flow	30	Widely variable (0 to 6000)

Table B-2

LEVELS OF SERVICES FOR FREEWAYS

AND EXPRESSWAYS

HIGHWAY CAPACITY MANUAL

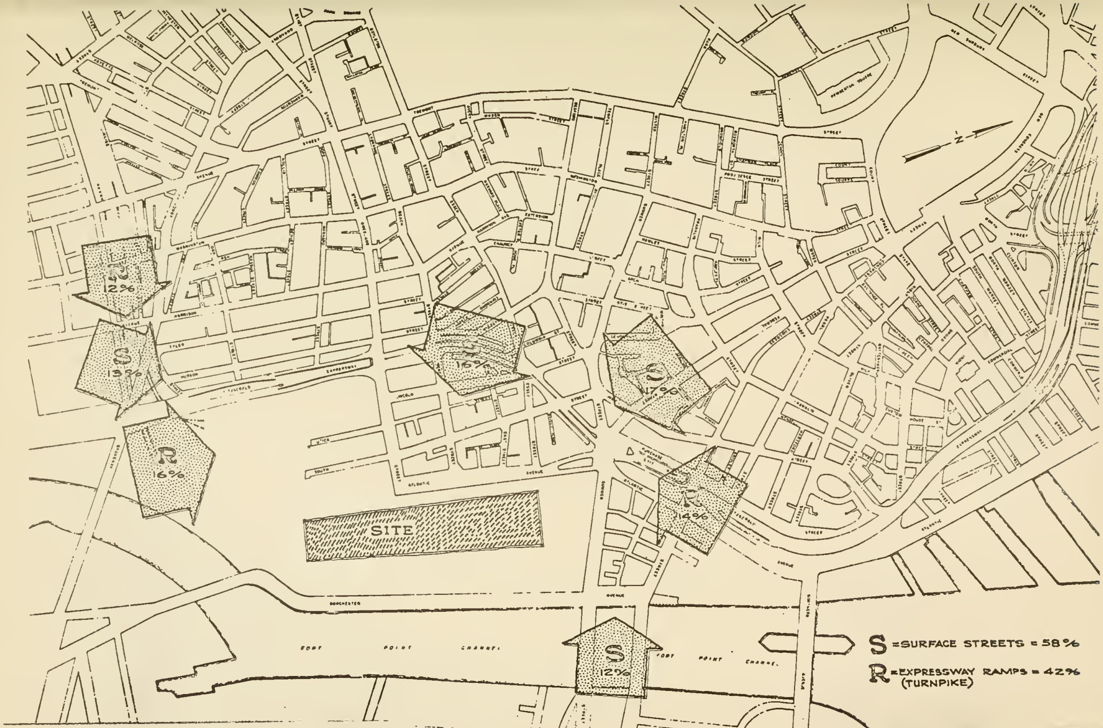


FIGURE B-1

DIRECTION OF VEHICULAR APPROACH
TO THE SOUTH STATION AREA

APPENDIX C

PEDESTRIAN ANALYSIS

Pedestrian Circulation Considerations

From consideration of parking patterns and the distribution of other modes of arrival, the patterns of pedestrian flow have been determined. The design criteria to be used is 45,000 spectators, maximum attendance for a baseball game. Football attendance would be at a higher level, but slightly longer times to discharge the spectators are acceptable.

The major patterns of approach are shown in the diagram below (Figure C-1).

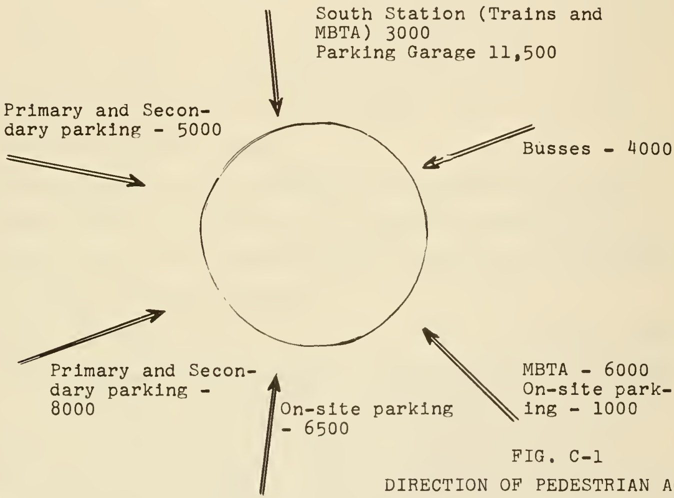


FIG. C-1
DIRECTION OF PEDESTRIAN ACCES

For spectators approaching from the north, either directly from the parking garage or from South Station, a covered overpass spanning the proposed harbor crossing and the railroad tracks will be provided. This overpass will connect directly with the moving sidewalk that is proposed

from the garage to Summer Street, providing convenient access to the central business district. A plan view and elevation of the overpass is shown in Figure C-2.

Spectators parking in the primary and secondary parking areas west of the stadium will proceed along Herald Street to the Broadway Bridge. (There are three overpasses to allow people parking north of the Mass. Pike to cross over to Herald Street). Ramps into the stadium directly from the bridge will be provided for these people. The majority of spectators parking in the on-site lot will also enter from the south by means of special ramps to the bridge from ground level. (Figure C-3)

Ground level entrances on the east will accommodate the remaining spectators parking on the site as well as those arriving at the Broadway MBTA station and those arriving by special bus or taxi. Access for those parking in the garage under the stadium will be contained entirely within the structure itself.

The design criteria for ramp capacity is 30 persons per minute per lane (22-inch width). From this it is possible to determine the minimum necessary size of the required ramps, assuming it is desirable to empty the stadium in thirty minutes:

FROM NORTH:	29,000 per/hr.		- 32 ft. wide
FROM SOUTH:	Parking area to Bridge:	13,000 per/hr.	- 15 ft. wide
	Bridge to Stadium:	39,000 per/hr.	- 41 ft. wide

Congestion at entrances can be avoided by careful consideration of the proposed number of entrances. Applying design criteria of the Highway Research Board for standard turnstiles with ticket collect it is possible to determine the required number of entrances. Since there is no need to collect tickets upon exit (turnstiles may even be the removable type), the entrance period is critical. The minimum required number of turnstiles is determined here: (Page C-3).

TURNSTILE CAPACITY: 25 persons/minute
1500 persons/hour

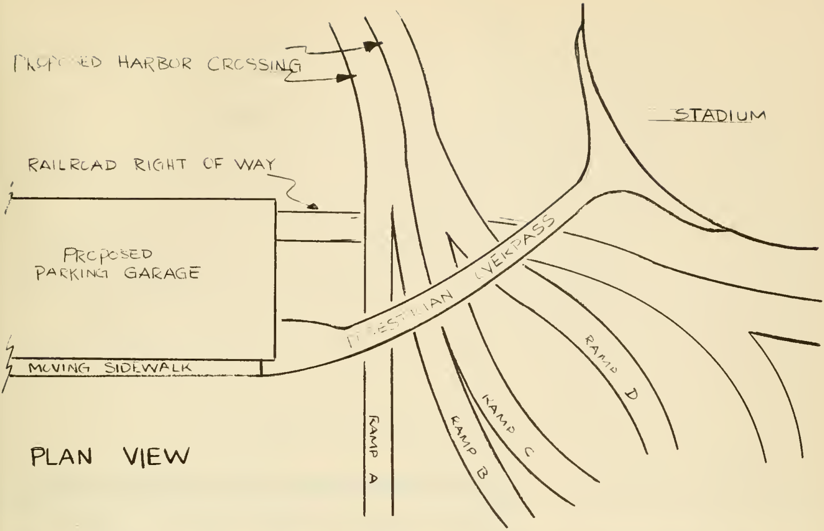
FROM NORTH:	
29,000 persons/hour	- 20 turnstiles
FROM SOUTH:	
39,000 persons/hour	- 26 turnstiles
FROM SOUTHEAST	
14,000 persons/hour	- 10 turnstiles
FROM NORTHEAST	
8,000 persons/hour	- 6 turnstiles

Their distribution is shown below:

FIG. C-4

DISTRIBUTION OF TURNSTILES

Ramps will be designed to provide easy access to all turnstiles they serve, and sufficient space will be allowed for any queues that may develop.



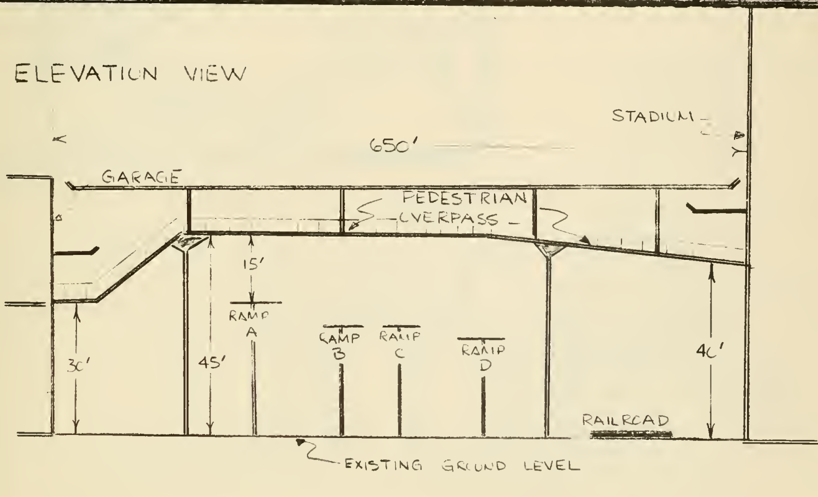


FIGURE C-2

PEDESTRIAN OVERPASS FROM GARAGE AND SOUTH STATION

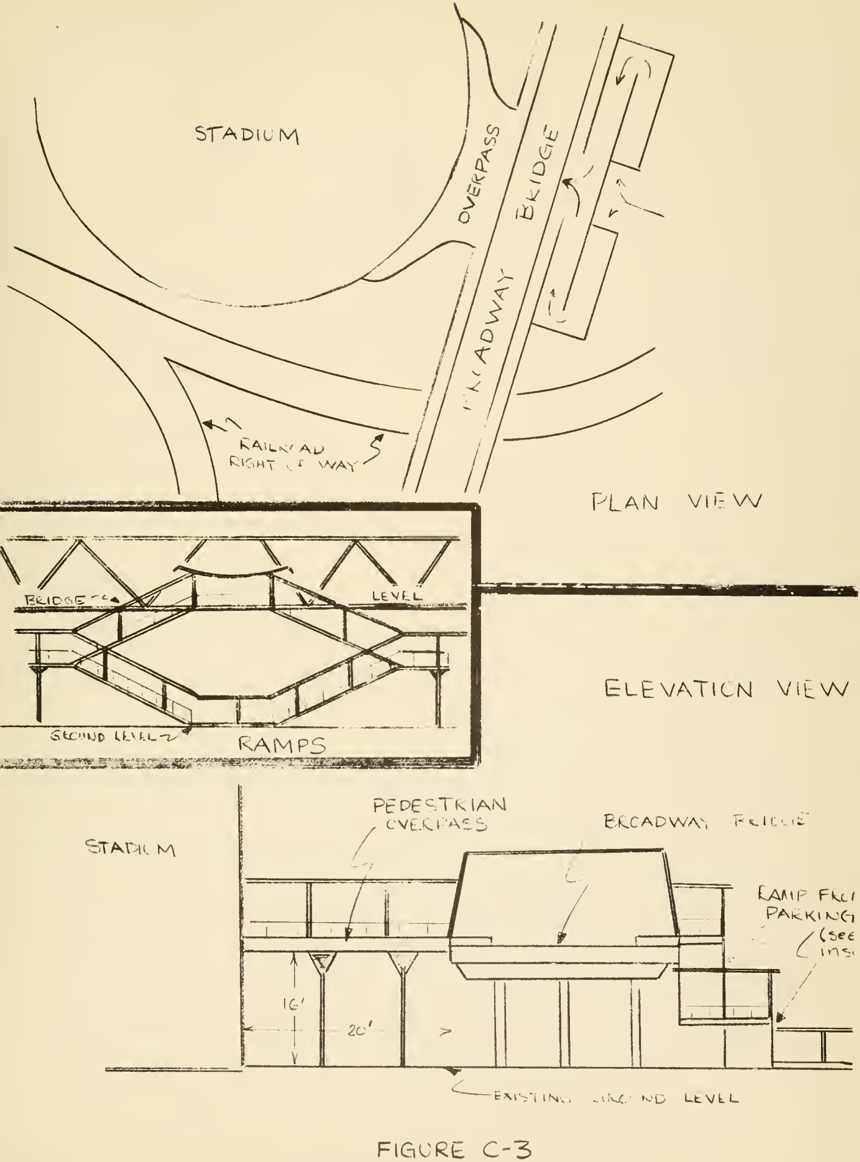


FIGURE C-3
PEDESTRIAN OVERPASS
FROM BROADWAY BRIDGE

APPENDIX D

SITE PLANNING

SITE GEOMETRY

The problem of site geometry is a critical problem, because the area available for the construction of a sports stadium is quite small. Complications arise from proposed or existing facilities not directly related to the stadium. The problem of site geometry is considered in two sections. The first section defines the boundaries of the site. The second section analyzes the problem of maintaining railroad service on the main line tracks to the south.

The southern boundary of the site is the Broadway Bridge, which is fixed. The western boundary is the main line tracks to the west and the John Fitzgerald Expressway. While the Penn Central tracks could be shifted northwest approximately fifty feet, our design leaves these tracks in their present location. In the northern portion of the site the South Postal Annex and an adjacent garage are presently being constructed. These buildings limit the location of the proposed Third Harbor Crossing, to be constructed by the Massachusetts Turnpike Authority. While it is not certain that a third harbor crossing will be built, our design enables construction of such a crossing in the location preferred by the Turnpike Authority as defined in their report, _The Preliminary Feasibility Study of the Third Harbor Crossing_ (June, 1968). Its location is assumed to be fixed.

The location of the eastern boundary of the site, Dorchester Avenue, is flexible. This street is to be relocated but its final location has not been fixed. The location of Dorchester Avenue,

as proposed by this study, has been shifted approximately 150 feet east of the location proposed in other reports by the Boston Redevelopment Authority. The location of Dorchester Avenue recommended in this report, as shown in Figure 2, does not create any major problems. The relocated street does not extend over the MBTA tunnel in the Fort Point Channel; this was done in order to avoid settlement problems. While it is probable that the Broadway-Dorchester intersection will be revised, our proposed location allows continued service on Foundry Street.

Within the site thus defined, the problem is one of placing a circular stadium(with a diameter of 700 feet), complicated by the necessity of maintaining service by the Penn Central Railroad to the south. A sewer conduit(20' x 40') is required by filling in the South Bay, and this is described fully in Appendix F. The design does not interfere with the main line tracks to the west, nor does it disrupt the freight storage tracks to the northwest. There are existing dead storage tracks north of the Broadway Bridge and to the east of the main line tracks going south. These tracks are not in use, nor is future use planned. There are four main line tracks going south from South Station. Although there are indications that only two tracks will be needed if the Southwest Expressway is constructed, we have allowed room for four tracks.

Four alternatives were considered before making the selection. These alternatives are listed below:

I: Stadium at ground level with the tracks below the stadium

II: Tracks at ground level with stadium raised above the tracks

III: Stadium at ground level with tracks to the east of the stadium

IV: Stadium at ground level with tracks to the west of the stadium

A stadium at ground level with tracks beneath it would require a tunnel with a minimum clearance of twenty-two feet. Railroad grades significantly increase fuel costs and limit the number of cars per train. On main line tracks, a maximum grade of 0.5% is preferred although a grade of 1.0% is permissible. Even with the maximum permissible grade, a stadium would require stilts of about ten feet unless the tracks were to start out twelve feet below ground level in South Station. Alternative I was thus rejected due to the following disadvantages: disruption of main line service, significant construction costs of a tunnel, additional costs of modifying South Station, and large foundation costs for the stadium itself.

The second alternative considered was to leave the main line tracks at ground level and raise the stadium on stilts approximately twenty feet above ground level. Although the first three of the problems encountered in Alternative I are eliminated, the foundation costs are still significantly increased(see Appendix E). For this reason, Alternative II was eliminated also.

The relocation of Dorchester Avenue made possible the consideration of the last two alternatives. Alternative III requires tracks with a high degree of curvature because of the geometric limitations imposed by the South Postal Annex and garage. Such curvature significantly increases maintenance costs as well as reducing operating speeds. Placing the tracks to the east would

involve clearance problems with the Broadway Bridge. Tracks on the eastern side of the stadium would also create problems with pedestrian and bus access from Dorchester Avenue and the Broadway MBTA Station.

Alternative IV places the railroad tracks on the western side of the stadium. The tracks would be outside the foundation area of the stadium. Construction of the relocated tracks would not significantly disrupt service to the south. There is adequate clearance for the tracks under the bridge and disruption of the freight yards to the south of the bridge will be minimal. The main line tracks going south would initially use the same tracks as the main line going west and then would branch off to the south as shown in Figure D-3. There will be a minimum of thirteen feet clearance between the nearest rail and the stadium. The clearance between the stadium and the bridge is fifteen feet. The stadium is approximately fifty feet from the relocated Dorchester Avenue. Although the location of Dorchester Avenue is flexible, the proposed location would allow the construction of ample facilities for the loading and unloading of busses to the northeast of the stadium.

Foundation considerations, both in terms of cost and complexity, are the main reason for constructing a stadium with tracks going around rather than underneath. As mentioned before, Alternative IV reduces the problems posed by Alternative III and is therefore the proposal that is advocated. The costs of removing the dead storage tracks and relocating the main line tracks as outlined here may be found in Appendix I.

FIGURE "D1"

TRACK DIMENSIONS

Track Length: maximum length = 1320 feet

Track Width: trying to minimize this figure

Number of tracks: four maximum (this may be reduced to two if the Southwest Expressway is constructed)

Minimum distances: 13 feet centerline to centerline

13 feet centerline to nearest obstruction

Total width: 65 feet

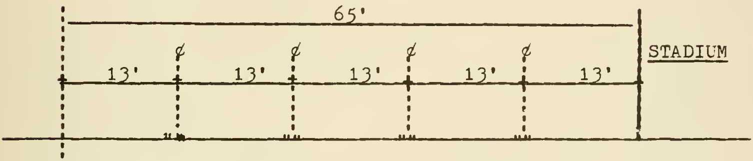


FIGURE "D2"

SITE BOUNDARIES

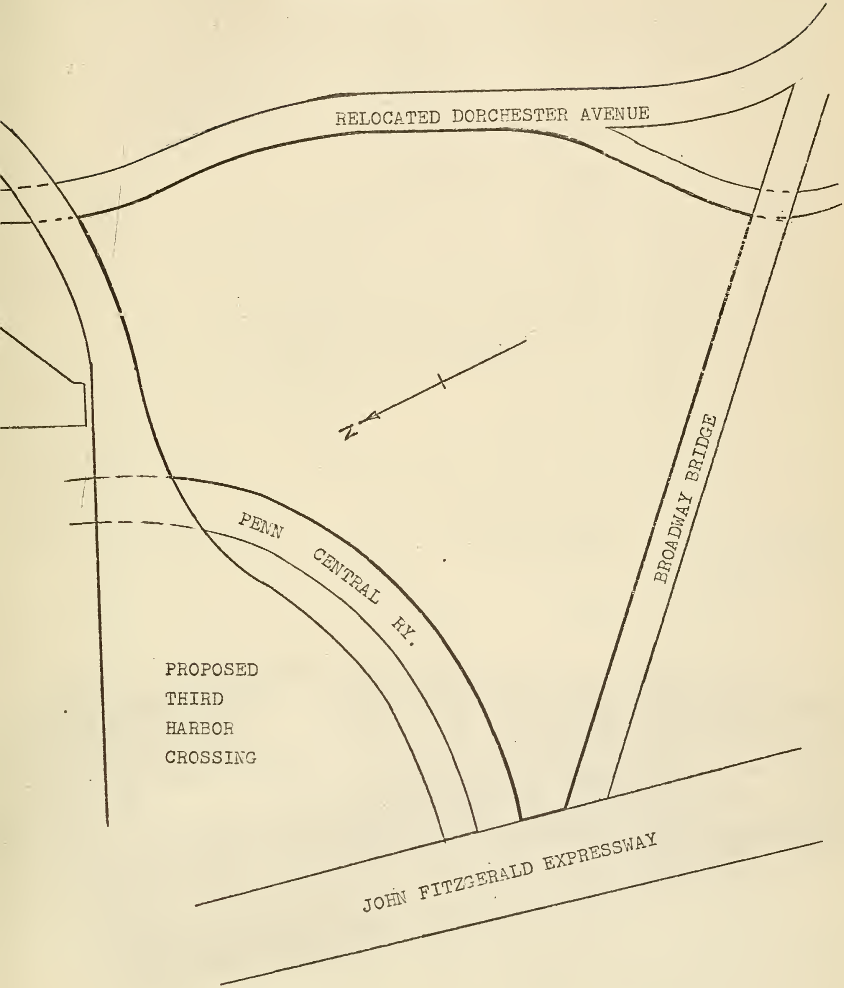
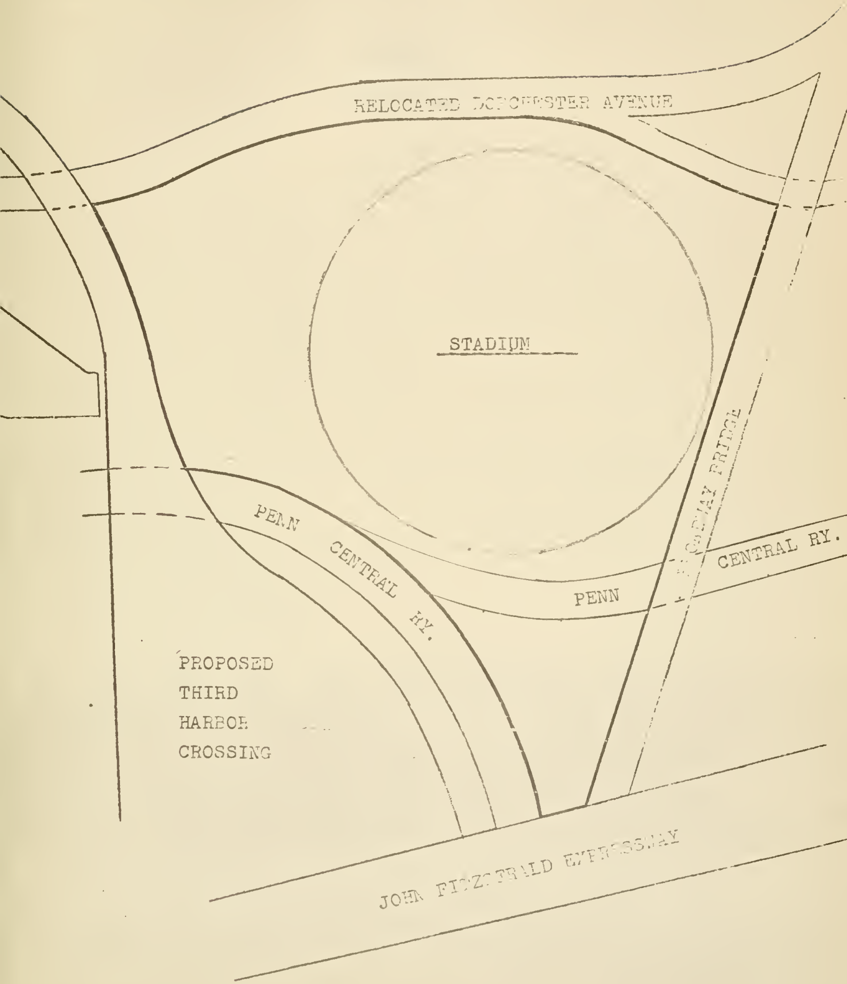


FIGURE "D3"

STADIUM PLACEMENT



APPENDIX E

FOUNDATION ANALYSIS

E.1 Geological Conditions

Soil conditions at the proposed site were formed during and following the last glacial period, some 20,000 to 25,000 years ago. The glacier deposited a deep stratum of unsorted, well graded, dense, blue glacial till or hardpan varying in thickness from 5 to 15 feet over the underlying rock, altered argillite. During the glacial retreat a thick stratum of blue clay was deposited over the till. The surface of this clay deposit was subsequently exposed to the air, erosion, and weathering. As the surface dried out, the clay consolidated to a medium to hard consistency and became yellow in many areas.

As the sea level rose again to submerge the clay following final retreat of the continental glacier, organic silt and shells and some peat were deposited above the clay stratum. These "recent" deposits occur from 5 to 25 feet below mean tide level.

Within the last 100 years miscellaneous sand, gravel, rock and wood fill has been placed over the area.

E.2 Soil Conditions

General--the soil data gathered for this report was obtained from the following sources.

1. Boring loop of the Boston Society of Civil Engineers
2. Reports of nearby projects (e.g., Dover Street Bridge)
3. Report of Engineering Properties of soils underlying M.I.T. campus
4. Conversations with soils engineers experienced in the Boston area
5. Visits to the site
6. Soil Mechanics by Lambe and Whitman

Soil Profile

The boring logs of the Boston Society of Civil Engineers provided 20 borings within or near the proposed site. These borings are plotted on figure E.1. Six cross-sections were then drawn from these boring logs. Figure E.2 represents a typical cross-section.

These soil profiles were immediately recognized to be similar to the soil profile of the M.I.T. campus. The engineering properties of the M.I.T. profile are completely outlined in a report, "Engineering Properties of the Soils Underlying the M.I.T. Campus." This report was used whenever data on or nearer to our site was not available.

E.3 The Problem

Aside from the very poor soil conditions which exist at the site, a visit to the site clearly showed other unique problems which had to be dealt with:

1. MBTA tracks ran through the middle of the site
2. The Fort Point Channel (South Bay section) would have to be filled
3. A drainage conduit would have to be constructed to replace the channel

E.4 Preliminary Investigations

A study of investigations made by other firms, and crude "hand" calculations clearly showed at the outset that supporting the stadium over the train tracks would involve a foundation cost of about 7.5 million dollars. Hence the first step in our investigation was to determine whether or not costs could be lowered by curving the tracks around the stadium. This investigation was carried out by the transportation division and the analysis is presented elsewhere in this report. The conclusion of the investigation was that the tracks could go around the stadium, and preliminary figures showed cost advantages to this plan. Hence, it was decided not to further consider a raised stadium.

We decided that the drainage conduit could be placed underneath the railroad tracks. This provided several advantages:

1. No structures or tunnels would lie under the stadium itself
2. By constructing the conduit as the first step of the project, and the train tracks as the second step, a "clear" site was assured for the rest of the construction as the old tracks could be removed, and the South Bay portion of the Fort Point channel could be dewatered.
3. The vast area of the playing field could be supported on the ground surface rather than some kind of raised mat.

The construction procedure is depicted in figures E.4.

E.5 Foundation Solution

With the above decisions in mind, two foundation solutions

were considered. More complete calculations of these solutions are included at the end of this appendix, and the following discussion will pertain to them.

E.5a <u>Deep Piles</u>

Filling the Fort Point Channel causes a significant increase in overburden on the thick, compressible day stratum. If any compression of this layer occurs after the piles have been driven negative skin friction will occur. Negative skin friction is a downward drag acting on the piles due to relative movement between the piles and the surrounding soil. The calculations in figures E.5 show that this skin friction would be 250 -300 tons for each pile. Deep piles driven into the altered argillite are limited to a 70 ton capacity; hence negative skin friction would cause failure. It is important to notice that any small amount of settlement would mobilize this force, hence pre-loading the site to reduce settlement after construction would be no assurance that negative skin friction would be prevented, as a small amount of settlement could still take place.

Another quick computation of piles alone was made to estimate the minimum amount that piles would cost if it were somehow possible to eliminate the negative skin friction problem. Even with a safety factor of 1 the cost was $1,500,000. As we will show, a satisfactory solution can be obtained at a cheaper price.

E.5b The solution which we feel best fits the site is a mixed foundation with the section of the site which is over the South Bay being supported by a floating foundation, while the section which is over original firm ground is supported by belled caissions resting on a hard clay layer 38 feet below ground surface. This foundation system is shown in figure E.6.

In considering filling South Bay, it was discovered that it would not cost much more to "fill" the channel with structure than it would be to fill it with fill. The advantage of a deep basement would be the increased parking that could be attained by building an underground parking lot in this space.

The preceding considerations are secondary to an important design feature. It is desirable to keep increases in overburden on the lower clay layers to a minimum, and for small differential settlements, any increases in overburden should be as uniform as possible around the perimeter of the building. If the entire building was on footings, one section would have an increased overburden of the weight of the structure plus the weight of thirty feet of fill underneath the structure. We attempted to balance these two overburdens by extending the structure downwards, actually supporting it by water pressure rather than bearing fully on the soil. In this manner the weight of the building and a significant amount of fill did not add to the overburden. Our settlement calculations (later in this section) show that this design is effective in bringing the predicted total settlements

around the perimeter of building to within one inch. Before filling the channel it is necessary to excavate the organic silt deposit (about 10 feet) down to the hard clay layer.

The preliminary cost analysis of this system is detailed in figures E.7 - E.11.

ITEMIZATION OF FOUNDATION COSTS

construction of caissons	$158,000
excavation in channel (under structure only)	$ 81,000
backfill in channel	$550,000
braced sheet-piling	$ 72,000
three foot structural mat	$170,000
substructure	$ 36,000
drainage conduit construction	$540,000
dewatering	$ 60,000
miscellaneous site preparation	$100,000
total estimated cost	$1,717,000

The unit costs used to derive these estimates were obtained from Building Construction Cost Data, published by Robert Snow Means Company, Inc. 1969. We must point out that these are estimates based primarily on volumes and that special site conditions may increase or decrease costs. A twenty five per cent "profit and contingency" margin has been allowed in all cases. The construction plan proposed in figures E.3 and E.4 promises to provide an economical approach with as little wasted time or effort as possible.

A preliminary settlement analysis was made using e- log p curves which were obtained from samples taken near the site, the increment in stress which would occur at the center of the 40 feet

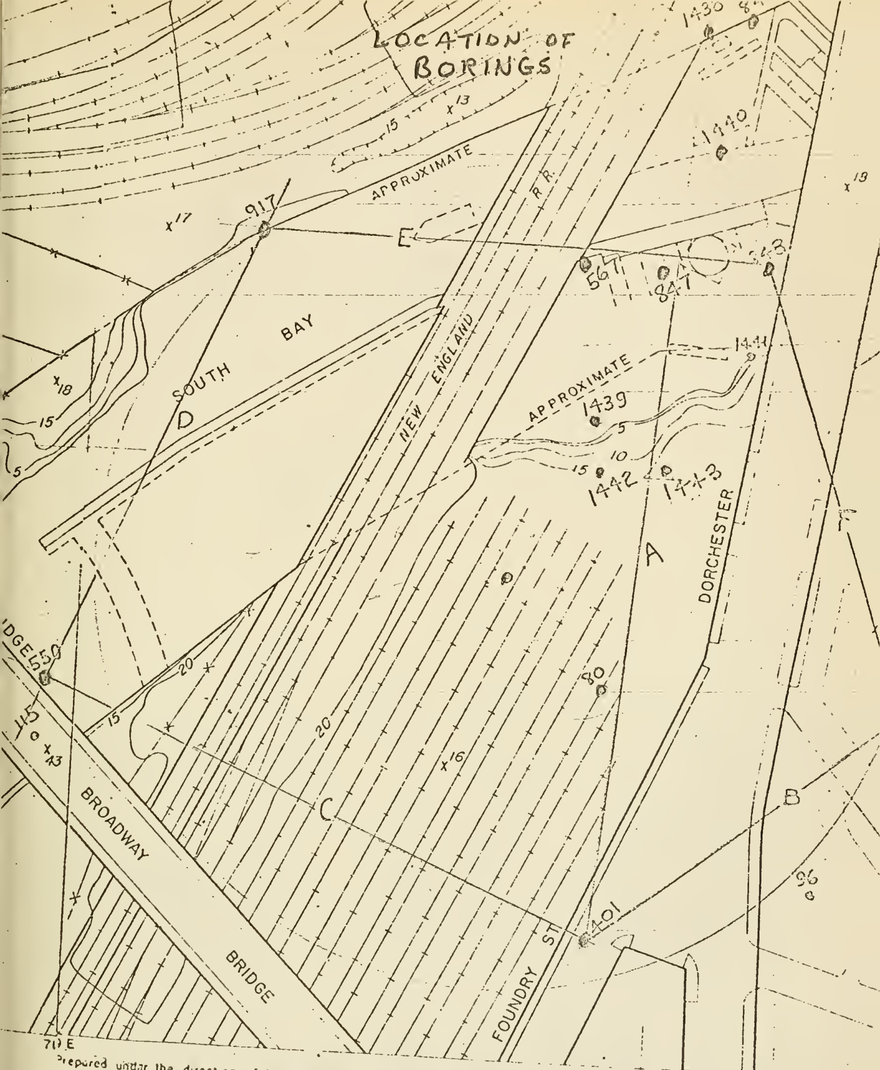
of normally consolidated clay underlying the site was arrived at by considering the South Bay to be a large strip load and using an appropriate stress bulb. The maximum total settlement arrived at in this manner is 5.4 inches. Experience in the Back Bay area and on the M.I.T. campus shows that approximately one half of this number or 2.7 inches of differential settlement can be expected to take place. Our structural engineers assure us that such a settlement is tolerable.

Settlement analysis of the section supported by belled caissions predicted a maximum total settlement of 4.7 inches and differential settlement of 2.3 inches. This again is within tolerable limits.

We decided to separate the two foundation sections with structural joints to allow the two systems to work independently. However, the low settlements predicted indicate that no problems should arise from differential settlement between the two sections.

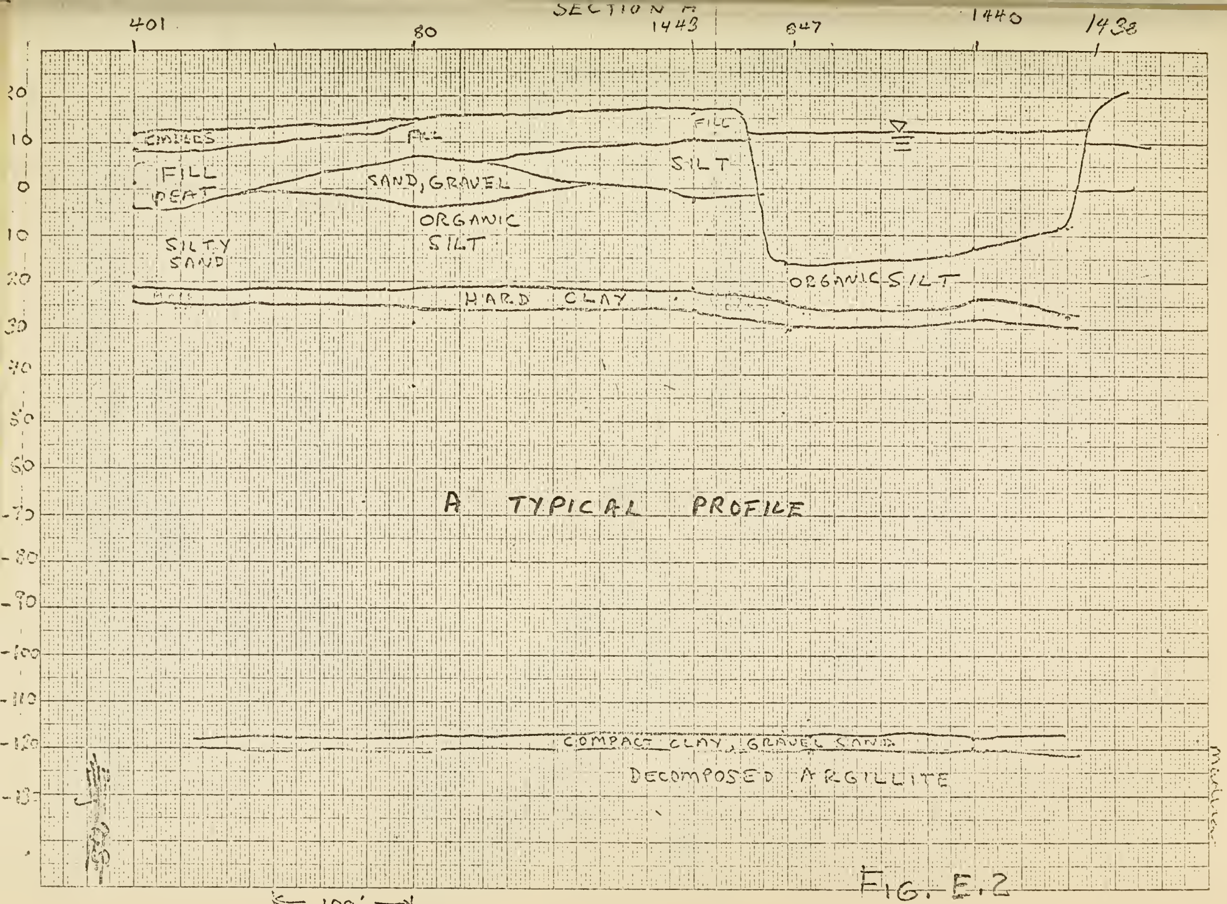
E.5c Movable Stands

The movable stands will be separate units driven on large pneumatic wheels by means of a winding mechanism. The wheels will be founded on a sand pad bed. Settlement of these stands is expected. However, since they are easily driven away on the wheel mechanisms it will be simple and cheap to periodically re-level the sand bed before the settlements approach an intolerable magnitude.



Prepared under the direction of the Boston Redevelopment Authority
STON Control by U. S. C. & G. S. and the Mass. Geodetic Survey
Mapped by Fairchild Aerial Surveys
ETTS Photography by Fairchild Aerial Surveys, April 1961
1962 North American Datum 1927
Control and Property Lines by
New England Survey Service Inc.

FIG. E.1



SECTION A
401
80
1443
847
1440
1438
20
10
0
10
20
30
40
50
60
-70
-80
-90
-100
-110
-120
CINDERS
FILL
PEAT
SILTY SAND
SAND, GRAVEL
ORGANIC SILT
SILT
HARD CLAY
ORGANIC SILT
A TYPICAL PROFILE
COMPACT CLAY, GRAVEL SAND
DECOMPOSED ARGILLITE
100'

FIG. E.2

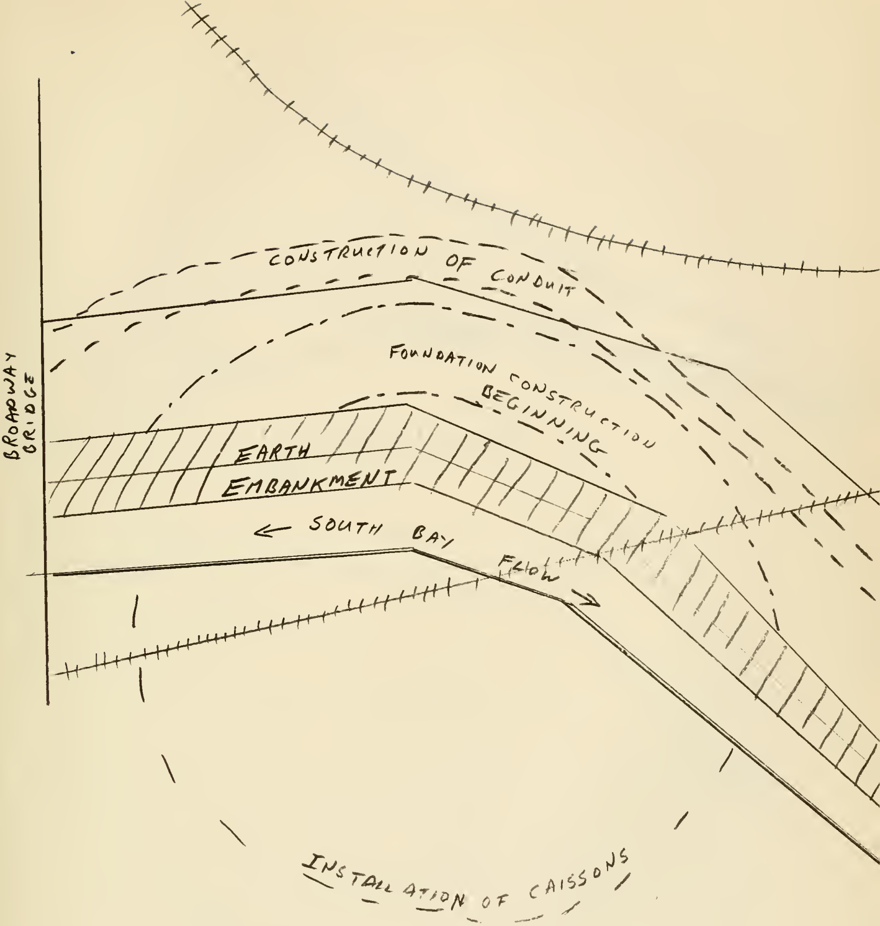


FIGURE E.3

FIRST STAGE OF THE CONSTRUCTION SEQUENCE

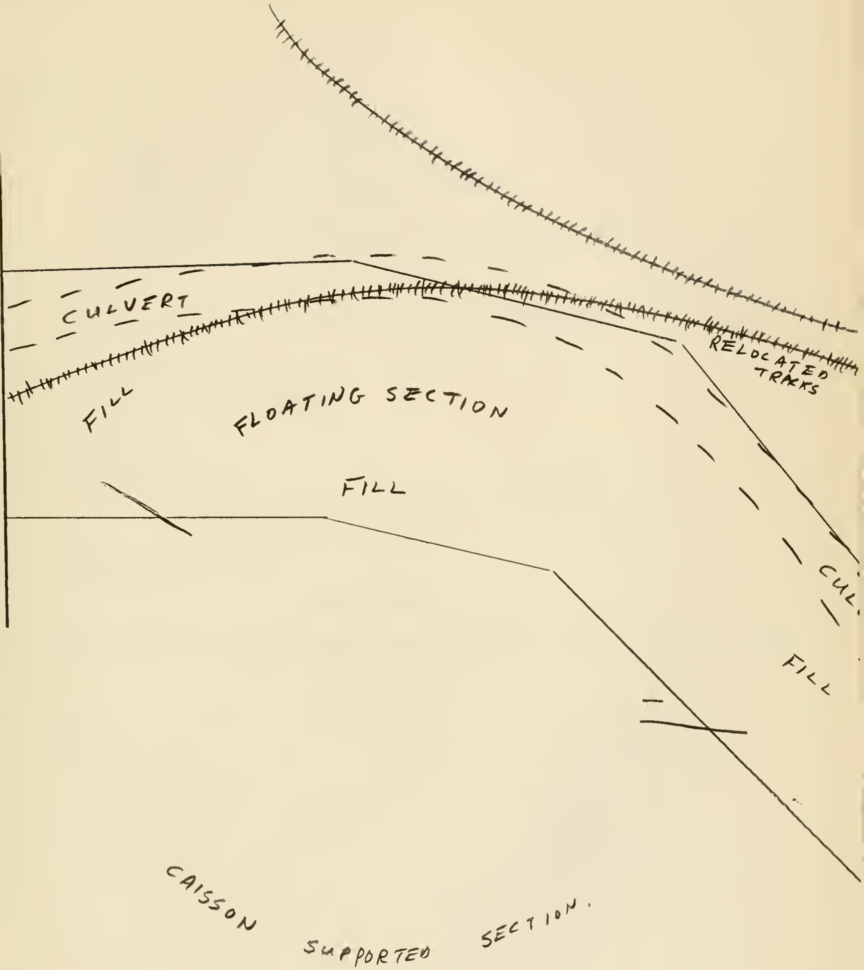


FIGURE E.4

SECOND PHASE OF THE CONSTRACTION SEQUENCE

Consideration of Piles

Fig. E.5

gative Skin Friction

N.S= $sLp \times \gamma LA$ or $nsL\pi d$ (smaller of 2)

S = Shear resistance of soil
L = length of pile above bottom of compressible layer
A = area enclosing pile cluster
P = perimeter of Area A
γ = average unit wt of soil (use γb for Below water table)
n = number of piles in cluster

N.S = 0.6 tons/ft^2 x 130ft x 16ft + 60 lb/ft^3 x 130ft x 16

N.S = 1250 tons + 6.25 tons for whole cluster

$= \frac{1256}{4}$ tons = 314 tons/pile

2nd formula

N.S/pile = $SL\pi d$
= 0.6 ton/ft^2 x 130 ft x 3.14 x 1 ft.
(= 250 tons/pile)

For above 70 ton capacity

Cost of piles

Absolute minimum # needed = $\frac{60{,}000 \text{ tons}}{70 \text{ tons/pile}}$ ← wt of structure live + dead load

= 860 piles

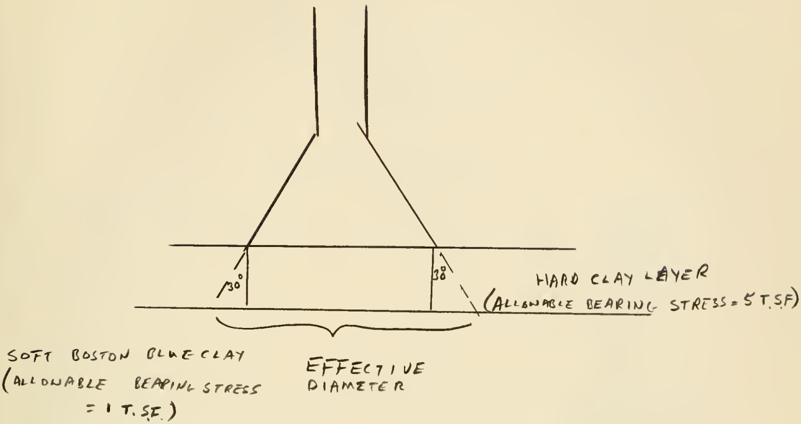
total ft. of piles

= 860 piles x 130 ft/pile
= 1.1 x 10^5 ft

cost = 1.1 x 10^5 ft. x \$13.50/ft
= \$1,500,000

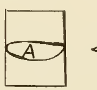
Figure E.7

Design of Caisson Bells



	Column	Load (Tons)	Diameter of Bell (feet)
(1)	outside	160	8.4
(2)		138	7.5
(3)		250	12.0
(4)	inside	80	4.0

Design of Caisson Columns



allowable stress = 900 psi

$$A = \pi r^2 = \frac{\text{Load}}{900 \text{ psi}}$$

Diameter of Columns feet	
(1)	2.0
(2)	1.7
(3)	2.3
(4)	1.3

Dimensions of Bells

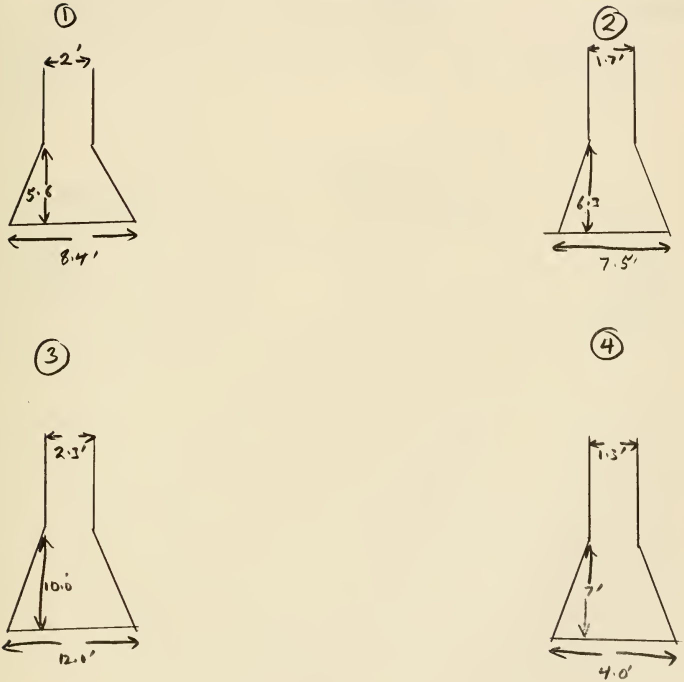


FIG. E.7

Figure E.8

Volumes of Columns

$V = \pi r^2 H$		cost/yd^3	cost/column
(1)	4 yd^3		\$ 320
(2)	2.4	\$80	\$ 190
(3)	4.7 yd^3		\$ 380
(4)	1.8 yd^3		\$ 145

Volumes of Frustrums

$V = 1/3\pi h(r^2 + r^{12} + rr^1)$	cost/yd^3	cost/caisson
(1) 5 yd^3		\$ 510
(2) 6 yd^3	\$ 102	\$ 612
(3) 17 yd^3		\$ 1734
(4) 1.5 yd^3		\$ 153

Total Cost

cost/caisson	# of caissons	total
(1) \$ 830	45	\$ 37,000
(2) \$ 802	45	\$ 36,000
(3) \$ 2114	35	\$ 74,000
(4) \$ 290	35	\$ 11,000
		\$ 158,000

FIG E.8

Figure E.9

Preliminary Design of Floating Section

Loads

Above ground structure	660 lbs/sq foot
structure Slab	450 lbs/sq foot
substructure	100 lbs/sq foot
Total	1210 lb/sq foot

Since no soil is to be removed for the excavation, we compute only the hydraulic pressures counter acting the buildings weight.

We propose that the building be founded at Elevation -14, 20 feet below mean water level for the site. The bottom of the channel is about Elevation -12 and the hard clay layer about Elevation -20, so eight feet of organic silt will have to be excavated and replaced with better fill.

FIG. E.9

Figure E.10

EXCAVATION

$$V = 2\pi r A \; \frac{\theta}{360}$$

$$= \frac{6.28 \times 305 \text{ ft} \times 1100 \text{ ft}^2 \times 163/360}{27 \text{ ft}^3/\text{yd}^3}$$

$$= 2.7 \times 10^4 \text{ yd}^3$$

Cost of Excavation = $\$3/\text{yd}^3$

Total cost	\$ 81,000

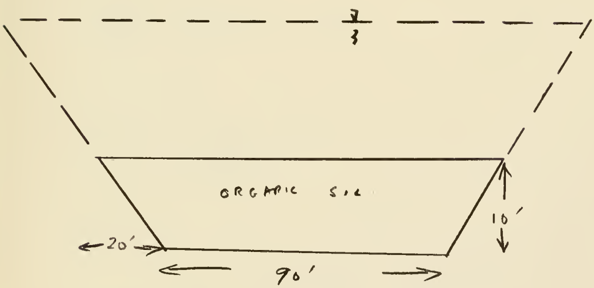
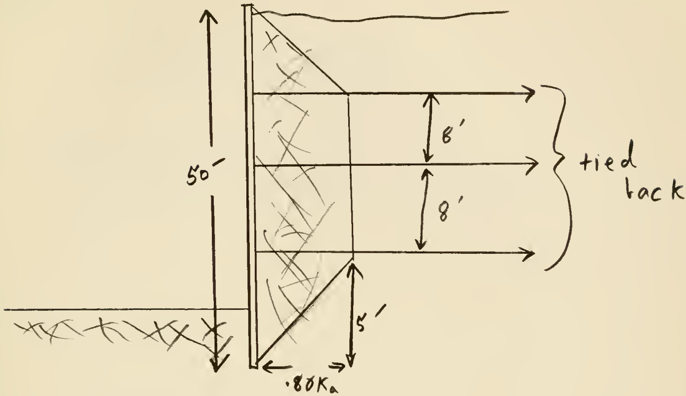


FIG E.10

Figure E.11

Preliminary design of Sheet piling



50' Sheet pile

$$Pa = 0.8\gamma HKa$$
$$= (0.8)\ (110\ lb/ft^3) \times 30\ ft \times 1/3$$

$$Pa = 880\ lb/ft^2$$

$$Mp = \frac{PaL^2}{8} = \frac{880\ lb/ft^2}{8} \times 64\ ft^2$$

$$Mp = 7240\ \frac{ft\text{-}lb}{ft}$$

$$Sp = \frac{Mp}{fa} = \frac{7240\ \frac{ft\text{-}lb}{ft} \times 12\ in}{20{,}000\ lb/in^2}$$

$$Sp = 4.35$$

Choose Sheet - Pile (steel)

V.S. Steel Symbol Mp 115

Bethlehem Symbol Ap 3

Inland Steel Symbol 1 22

Equivalent Sheeting

$S = 5.4\ in^3/ft$

FIG E.11

The weight of this piling/100ft = 220,000 lb

Cost of piling: $ 175/ton

cost/100 ft = $ 16,000

Total sheet piling needed: 450 ft

total cost of sheet piling: $ 72,000

APPENDIX F

STADIUM CONFIGURATION

APPENDIX F. STADIUM CONFIGURATION AND SEATING

F.1 General

The content of this appendix is composed of four major topics:

(1) Site constraints and the geometric configuration of the stadium.
(2) Stadium plans, space requirements.
(3) Seating desirabilities, arrangements and capacities.
(4) Traffic flow.

F.2 Stadium Configuration

The South Station site places serious constraints upon the stadium size and location.

Our decisions to relocate Dorchester Avenue and to swing the railroad tracks west of the stadium (rather than place the stadium on stilts over the railroad tracks) led to the necessity of a relatively small stadium.

In addition to the necessity of a small stadium is the necessity of an efficient and economical stadium. It follows that the stadium should be structurally simple, should provide rapid egress and ingress, comfort and enjoyment to the user, and should meet the playing field and space requirements of the athletic teams.

F.2.1 Shape

Many stadiums built in recent years have met the above demands with a circular geometry. For the following reasons, a circle seems to be the best shape possible for a stadium on the South

Station site:

(1) The circle will enclose more space with less perimeter than will any other geometric form. This point is extremely important. The playing fields, seats, offices, corridors, etc., place a lower limit on the total area required. Providing for this area in a small stadium requires the enclosure of as much space as it is possible to obtain.

(2) A circular stadium is structurally simple and economical. Each section through the stadium will reveal the same structural frame, which can be easily analyzed and used to estimate the total structural cost of the stadium. Furthermore, the constant section throughout the stadium implies a minimum member of different structural members which can be manufactured, fabricated, and constructed at a relatively low unit cost.

(3) The circle places the greatest number of seats close to the playing fields. Furthermore, the radial orientation of the seats directs the attention of every spectator toward the center of the playing fields.

(4) Radial aisles permit maximum efficiency of ingress and egress. Also, the circulation through the building to any seating section is minimized.

(5) Provisions for a stadium roof - future or present - could most easily and economically be adapted to a circular structure. The spherical surface or dome (the three-dimensional counterpart of the arch) is the most efficient and economical method for covering long spans in structures.

F.2.2 Size

The size of the South Station stadium was limited by the following site constraints. As mentioned above, Dorchester Avenue will be relocated farther to the east and the railroad tracks will be positioned west of the stadium. Also, the Broadway Bridge lies to the south of the stadium. With clearances of 20 feet from Broadway Bridge, 50 feet from Dorchester Avenue, and 8 feet from the nearest railroad track, the maximum stadium diameter was set at 700 feet (see Fig. F.1). This diameter was large enough to

provide the areas required for the baseball and football playing fields (see F.3) but created some problems with respect to the seating arrangements and spectator line-of-sight (see F.4.2).

F.3 Staduim Plans and Space Requirements

F.3.1 Playing Field Orientation

The Red Sox require that the axis running from home plate to centerfield lie in a north-easterly direction. Figures F.2 and F.3 show the orientation of the playing fields. The direction of the long axis of the football field is N 13°E. In Figure F.3 it can be seen that seating section M has been rotated counter-clockwise so that it is parallel to fixed section F. The long axis of the football field has been set parallel to both sections. This field arrangement requires only one seating section to be rotated and also requires the least actual field area.

F.3.2 Typical Cross-Sections

Figure F.4 shows the various structural sections to be found in the stadium. These sections are not intended to be either exact or final designs, but have been developed in this feasibility report in order to investigate seating conditions and structural costs, given the limitations imposed by the South Station site.

In Figure 4(a) is shown section A-A of Figure F.2, in (b) section B-B, and in (c), the centerfield section C-C. Section A-A

includes a fixed bank of seats (Section F) on the third base side of the baseball field and a movable bank of seats (Section M) on the first base side. Three-fourths of the stadium structure consists of the upper deck arrangement shown in (a) and (b). The upper deck beams, which cantilever 25 feet on either end, are supported by column rows 3 and 5, whereas column row 4 supports the interior portions of the six floor levels. The fixed seats between column rows 2 and 3 encircle three-fourths of the stadium, while those between rows 1 and 2 encircle only one-half of the stadium.

The centerfield Section C-C was developed to allow more fixed seats to be added in the position of column rows 1 and 2 around the home plate area and to keep the number of seats in Section M small. In the centerfield section column rows 1, 2, and 3 have been eliminated and retractable seats have been added (see F.4), making it possible to shift home plate along its northeasterly axis toward centerfield. The upper deck in the centerfield section is 36 feet lower than and 30 feet narrower than the deck in the rest of the stadium.

Sections D-D and E-E of Figure F.3 are shown in Figure F.4(d). Section D-D is obtained by the movement of Section M seating, whereas Section E-E is obtained by moving into position a 50 feet wide retractable seating section. The centerfield section Figure F.4(e) is obtained by moving into position an 80 feet wide retractable

section.

Section A-A shows that there are only two separate seating levels - upper and lower - with no intermediate mezzanine levels. It was found that seats added by a mezzanine level could be provided in the two main levels. Level E contains an overhanging floor area which is to be supported in part by the upper deck cantilever. This area will ring three-fourths of the stadium, will have a safety glass facade, and will provide space for radio and TV, the press, the private boxes of the team owners, and auxiliary scoreboards.

The sections developed for this study do not include a roof of any kind. The reasons for having no roof are listed in Appendix H. The outer circle of the upper deck does include a wall which provides support for the banks of field lights which ring the stadium.

F.3.3 Stadium Plans and Space Requirements

Typical dimensions for a baseball field are 330 feet down both foul lines and 410 feet to straight-away centerfield. Also, baseball requires a distance of 60 feet behind home plate. The total distance of 470 feet is the smallest interior diameter possible. However, with this diameter very few field level seats can be provided behind home plate. Thus, 50 feet was added to the internal diameter, producing an inner column row 2 of 520 feet diameter. The ring between column rows 2 and 5 is 90 feet wide. This

distance was divided into three bays of 30 feet each, resulting in column rows 3 and 4 (Table F.1).

TABLE F.1 Column Configuration

Column Row	Radius	Column Spacing	Wall Height
1	210'	16.5'	16'
2	260'	20.4'	28'
3	290'	22.8'	-
4	320'	25.1'	-
5	350'	27.5'	-

Table F.1 is based upon eighty radial column lines. The reasons for using eighty bays in the structure are discussed in Appendix G.

The home run line down both foul lines (column row 2) is a wall 28 feet high. The centerfield portion of the home run line is a chain fence 7 feet high. The necessity of a 28 feet high wall is dictated by seating section slopes. Between rows 1 and 2 the slope is 13°, between rows 2 and 3, 22°. Given a certain grandstand width, the height of the outer edge is determined by the above slopes. Because of the 50 feet wide section (between rows 1 and 2) and the width of the Sections M and F, the wall height of 28 feet is necessary.

The stadium cross-sections discussed above were analyzed in terms of the usable floor area they provide. A discussion of

spectator flow through the corridors and ramps is included in F.5.

Approximate floor area requirements are listed in Table F.2.

TABLE F.2 Floor Area Requirements

Floor Use	Number	Area (S.F.)	Total (S.F.)
(1) Restrooms			
A-Men	25	800	20,000
B-Ladies	25	800	20,000
(2) Concessions			
C-Concession Stands	15	1,500	22,500
	15	800	12,000
D-Storage	35	300	10,500
E-Sub-commissaries	10	800	8,000
F-Commissary		15,000	15,000
(3) Offices			
G-Stadium Mgt.			4,000
H-Football			6,000
I-Baseball			10,000
J-Advance Tickets			10,000
(4) Press and TV-Radio			
K-Baseball	100 men	4 L.F./man	5,000
L-Football	100 men	4 L.F./man	5,000
M-Camera Booths	10	-	-
(5) Restaurants			
N-Stadium Club			13,000
O-Public			12,000
(6) Protection			
P-First Aid	2	700	1,400
Q-Police			1,600
(7) Maintenance			
R-Field Equipment			14,000
S-Equipment Repair			3,000
T-Shop			3,000
U-Ground Keeper			1,500
(8) Utility Rooms			
V-Electrical	4	1,250	5,000
W-Mechanical	4	1,250	5,000
(9) Team Rooms			
X-Baseball Lockers	2	6,000	12,000
Y-Football Locker	2	6,000	12,000
Z-Officials	1	2,500	2,500
AA-Bands	2	2,500	5,000
BB-Others			3,000

(10) Stadium Personnel			
CC-Ushers	2	4,000	8,000
DD-Ticket Sellers	1	4,000	4,000
EE-Concessionaires	2	6,000	12,000
(11) Seat Storage			
FF-Retractable	2	6,000	12,000
		TOTAL	278,000 S.F.

In addition to these fairly well-defined areas there are small areas required for miscellaneous uses such as public address, trash, scout platform , and organist areas.

The areas listed above are shown in Figure F.7. At each floor level A through G the shaded areas are labelled according to their use and the approximate floor area is listed. The unshaded areas are ramps, corridors, and ticket lobbies. A comparison of the area listed in Figure F.7 with those in Table F.2 reveals that it is possible to provide easily all of the required floor area within the stadium under study. However, the arrangements shown need to be examined in terms of their location and efficiency.

F.4 Seating

The seating requirements for baseball and football are incompatible. To design a stadium for both events is a difficult problem, and especially so with a stadium that can be no larger than 700 feet in diameter. This section analyzes whether or not the seating requirements can be satisfied within the limitations set upon the stadium by the South Station site.

F.4.1 Seating Desirabilities

The best baseball seats are located (1) behind home plate at field level; (2) along either base path at field level; and (3) behind home plate in the upper deck. The most desirable seats for football are upper deck seats adjacent to the middle third of the football field. Given either condition it becomes extremely difficult (and expensive) to provide for the ideal demands of the other condition. For example, the excellent baseball seats behind home plate at field level become poor football end zone seats. It soon becomes obvious that both conditions must be provided for and that the respective poor seats must be accepted. However, the circular stadium configuration is perhaps the most economical and efficient solution to this problem.

The seating capacity of the stadium also involves a compromise of the demands of baseball and football. The Red Sox would be perfectly happy with no more than 42,000 seating capacity. The Patriots would like to have as many seats as could be provided, but would be satisfied with 65,000 seating capacity. The difference of 23,000 seats might be achieved in three ways: (1) design a 65,000-seat stadium for football, which can be used for baseball by hiding 23,000 seats beneath scoreboards or huge cloths; (2) build a similar stadium, but provide 23,000 seats that can be dismantled or retracted; (3) build two stadiums, one of 42,000 capacity, the other of 65,000 capacity. The third solution is impossible on the given site. The second solution would be very expensive in terms of the mechanical system required, whereas the first solution

would be undesirable from an architectural viewpoint. A workable solution was to design a stadium of around 53,000 maximum capacity which could be reduced to around 45,000 capacity by means of retractable seating sections.

F.4.2 Seating Arrangements and Capacities

The lower deck seating arrangements for baseball and football are shown in Figures F.2 and F.3, respectively. The stadium has been cut parallel to the ground at level D (+56 feet) in each case. The upper deck arrangement is shown in Figure F.5. Estimates of baseball and football seating capacities are given in Table F.3, from which it can be seen that the number of seats required can easily be provided.

It was possible to obtain a seating differential of about 8,000 seats with the use of retractable seating sections, which are shown cross-hatched in Figure F.3 and are sketched in Figure F.6. The two sections at the foul lines are 30 feet wide; the centerfield section is 80 feet wide. These sections will operate in one of two ways, as sketched in Figure F.6. In (a) the sliding seats are integral with the seating supports, which slide along tracks that can easily be laid and removed. In (b) the sliding seats are supported on a separate removable frame. During baseball season the foul line sections can be stored beneath the permanent seating sections, while the centerfield section will be stored behind the home-run fence. It may be possible to increase the seating diffenential by blocking out a portion of the upper

TABLE F.3 Estimates of Seating Capacities

BASEBALL ARRANGEMENT

Lower Deck

$(290^2 - 260^2)\frac{\pi}{6} = 8,600 \times \frac{270}{360} = 6,500$

$(260^2 - 210^2)\frac{\pi}{6} = 12,300 \times \frac{180}{360} = 6,200$

$(210^2 - 180^2)\frac{\pi}{6} = 6,100 \times \frac{180}{360} = 3,000$

$(180^2 - 150^2)\frac{\pi}{6} = 5,200 \times \frac{130}{360} = 1,900$

5,100 x ½ = 2550 Movable Section M

$2 \cdot \frac{1}{6} \cdot \frac{1}{2} \quad (300\pi \times \frac{65}{360} \times 150) - 190\ (150 - 22) \quad = 200$

Subtotal: 17,800

Upper Deck

$(375^2 - 265^2)\frac{\pi}{6} = 36,900 \times \frac{270}{360} = 27,6000$

$(375^2 - 295^2)\frac{\pi}{6} = 28,100 \times \frac{90}{360} = 7,000$

Subtotal: 34,600

52,400 TOTAL

FOOTBALL ARRANGEMENT

Lower Deck

$12,300 \times \frac{180}{360} = 6,100$

$8,600 \times \frac{90}{360} = 2,200$

Retractable ~ 8,300

17,800

26,100

Upper Deck 34,600

60,700 TOTAL

Note: These estimates are based on the assumption of 6 sq. ft. per seat.

deck with a collapsible scoreboard system.

As mentioned above, only one bank of seats need be rotated to convert the stadium from baseball to football use. The desire was to keep this movable section of seats as small as possible in order to keep the costs of the structural support and foundation low. Approximately 2500 seats can be provided in section M, which can be supported and rolled on huge pneumatic tires or tracks.

The necessity of having any movable stands at all arises out of the desire to fit both playing fields within the smallest possible area. Also, it is desirable to have higher seats behind each end zone area. By rotating section M so that it is parallel to section F and the football field, the end zone seats are at an elevation of sixteen feet above field level (see Table F.1).

Because of the small size of stadium required, a problem arises with respect to upper deck seating, especially in the outfield areas. The upper deck is inclined at an angle of 35 degrees. By extending the interior edge of the upper deck until it intersects the playing field, a circle with a radius of about 190 feet is obtained. Thus, there are certain areas of the baseball outfield which some spectators will not be able to see. Although undesirable, this feature must be accepted in a small stadium which must include over 50,000 seats.

F.5 Spectator Flows

A smooth, steady flow of spectators throughout the stadium is important,especially immediately after sporting events. This flow is assured with the provision of wide aisles, corridors, and

ramps. However, the South Station site limits the outside access to the stadium, thus creating problems as to the proper locations of exits, entrances, and ticket booths.

F.5.1 Exits, Entrances, and Ticket Booths

The directions of approach to the stadium and the respective numbers in each direction have been developed in Appendix C. Four ground-level entrance gates have been provided on the eastern half of the stadium. These gates include a total of ten ticket booths at the edge of the stadium and a total of sixteen turnstiles along column row 4. In addition to these entrances (which may also be used as exits), five separate exit gates have been provided at ground level to facilitate post-game egress.

There are no ground-level accesses to the stadium from the west. The southern entrance at level B is provided with thirteen ticket booths and 26 turnstiles. The northern entrance at level D is provided with ten ticket booths and twenty turnstiles. Access from the parking garage beneath the northern sector of the stadium to the stadium superstructure is by elevator.

F.5.2 Ramps, Corridors, and Aisles

Vertical movement within the stadium is accomplished by means of double sets of ramps which ring the circumference of the stadium. At each stadium level except level A there are seven platform areas into which four ramps feed - one ramp on both sides of the platform area from the levels above and below. All ramps are twelve feet wide and have a maximum slope of about one in ten. These ramps

are each capable of handling about 2800 people in a time of about ten minutes. Vertical movement from level A to level B is provided by three series of escalators between the four entrance gates.

Horizontal circumferential movement is provided by corridor rings which are at least 25 feet wide on each level. These corridors must provide adequate passage space from the ramp platforms to the grandstand vomitories and also provide ample space so that large groups of people buying refreshments at concession stands will not interfere with the normal corridor flow.

Radial movement from corridors to grandstand vomitories occurs at levels B, D, and G by means of eight feet wide passageways. In the upper deck there are twenty such passageways, each one capable of handling 2000 people, which is the number of people in two seating sections. The seating sections themselves are separated by four feet wide aisles which lead to the vomitories. The vomitories are eight feet wide and about fifteen feet deep. In the lower deck there is direct access from level D to the seats between column rows 2 and 3. Access to lower level seats, including seating sections M and F, is provided from level B by means of ten passageways leading to vomitories. The general directions of spectator flow are indicated by the arrows in Figure 7.

FIGURE F.1. SOUTH STATION

SITE CONSTRAINTS

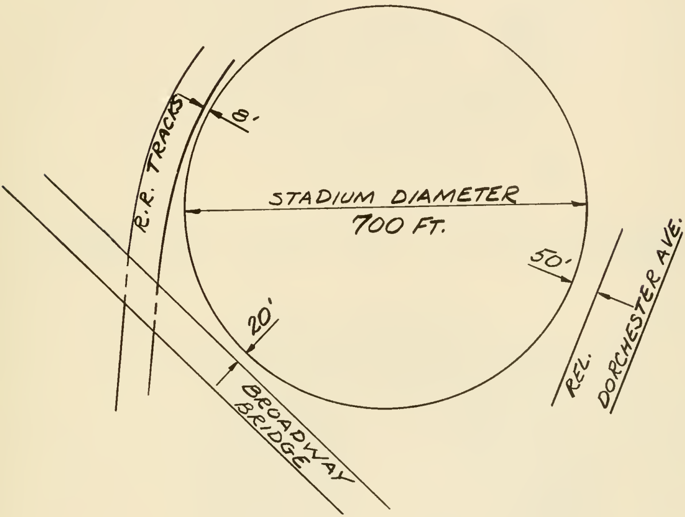


FIGURE F.2. LOWER DECK SEATING ~ BASEBALL

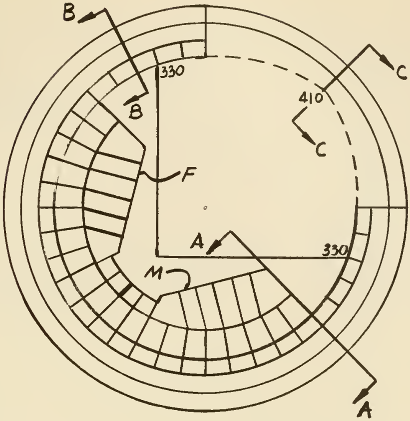


FIGURE F.3. LOWER DECK SEATING ~ FOOTBALL

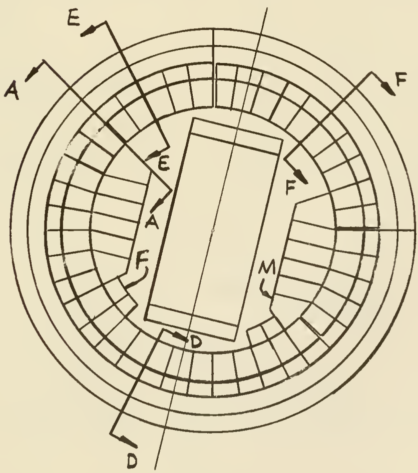


FIGURE F.4. TYPICAL CROSS-SECTIONS

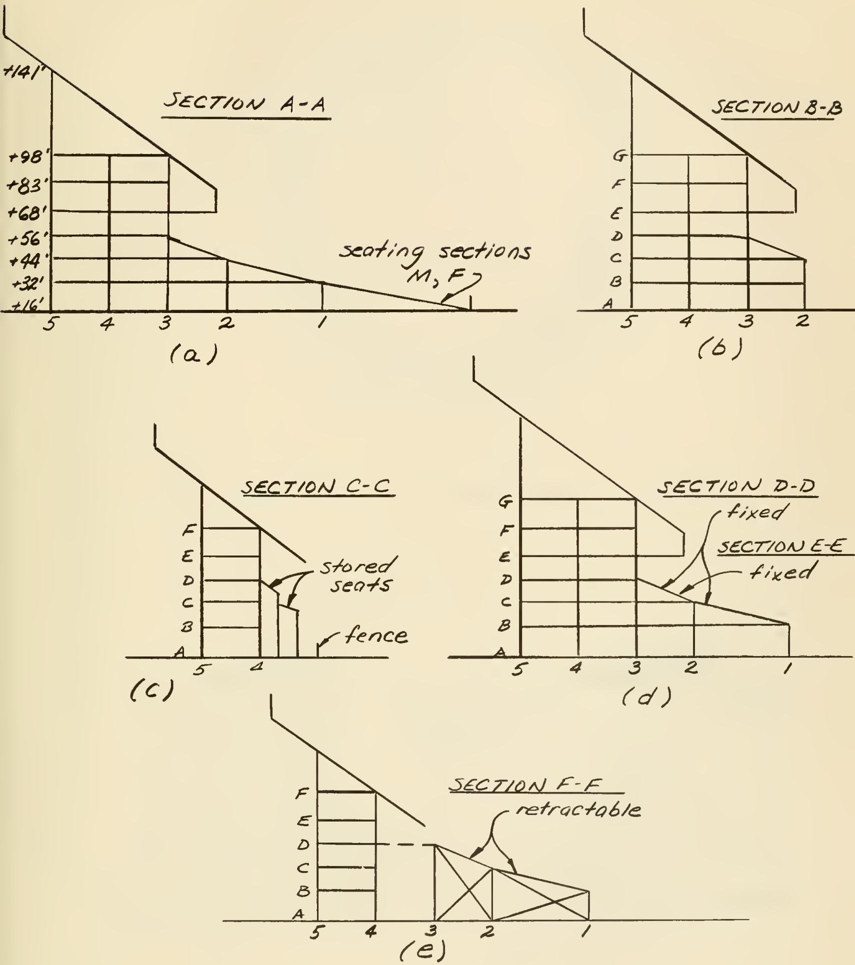


FIGURE F.5. UPPER DECK SEATING.

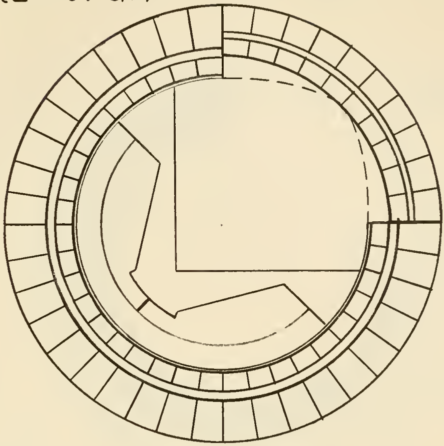
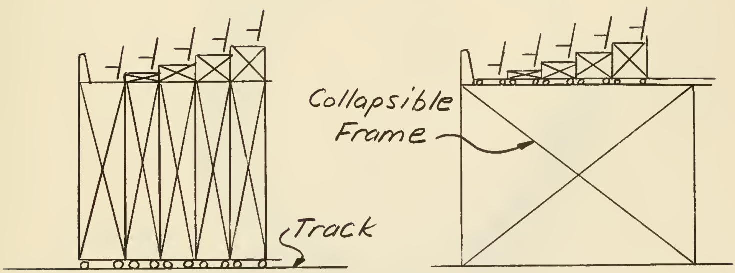


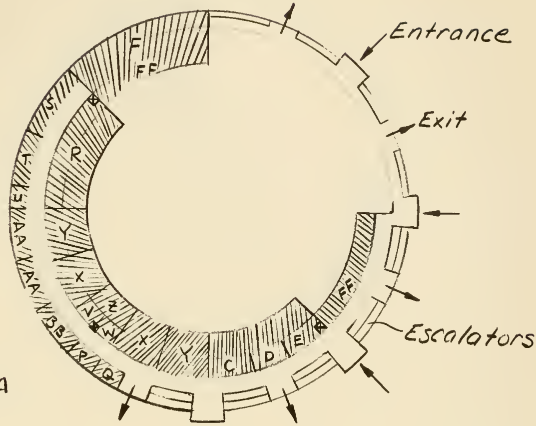
FIGURE F.6. RETRACTABLE SEATS.



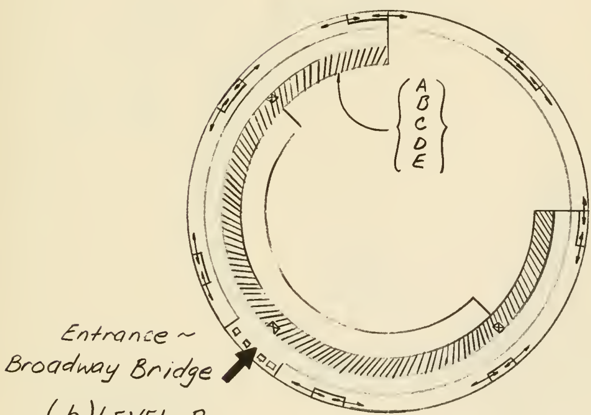
(a) Rolling Frame (b) Rolling Seats

FIGURE F.7. FLOOR AREA USE

C - 400 S.F.
D - 400 "
E - 400 "
F - 15,000 "
P - 1500 "
Q - 1500 "
R - 16,000 "
S - 3000 "
T - 3000 "
U - 1500 "
V - 1500 "
W - 1500 "
X - 12,500 "
Y - 12,500 "
Z - 2900 "
AA - 5000 "
BB - 3000 "
FF - 12,500 "

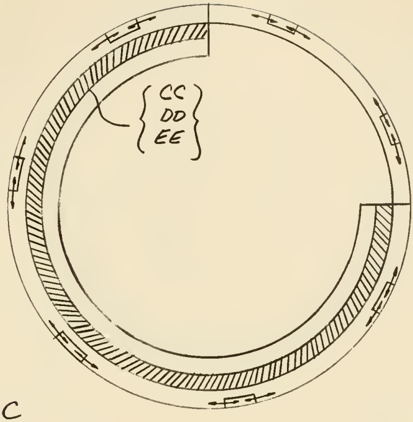


(a) LEVEL A
+16'

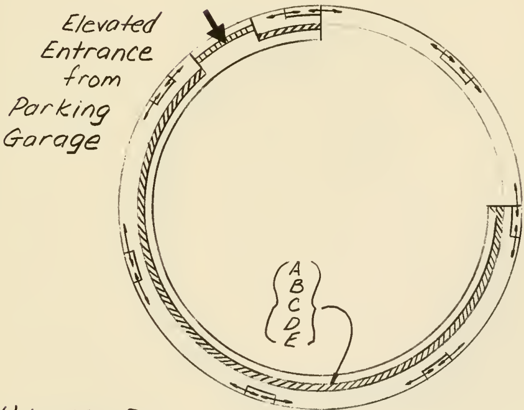


(b) LEVEL B
+32'

FIGURE F.7.(CONT.)

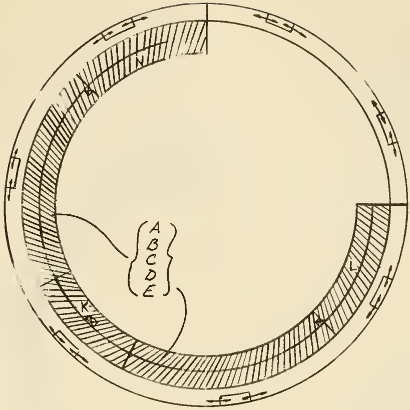


(c) LEVEL C
+44'

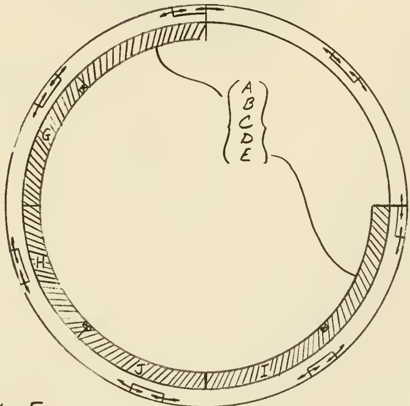


(d) LEVEL D
+56'

FIGURE F.7. (CONT.)



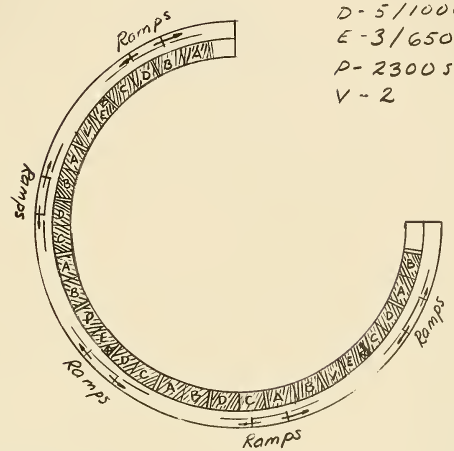
(e) LEVEL E
+68'



(f) LEVEL F
+83'

FIGURE F.7. (CONT.)

A – 6/1250 S.F.
B – 6/1250 S.F.
C – 5/1000 S.F.
D – 5/1000 S.F.
E – 3/650 S.F.
P – 2300 S.F.
V – 2



(g) LEVEL G
+98'

APPENDIX G

STRUCTURAL ANALYSIS

Appendix G.

Structural Analysis and Design

General:

Because structural weight as well as cost considerations would be influential in determining the feasibility of a stadium on this site, it was decided that both, reinforced concrete and steel structural systems would be designed. It was expected that the reinforced concrete structure would be less expensive than steel but that it might weigh sufficiently more that this benefit would be overborne by other factors.

Both systems were to be designed in accordance with the loading conditions specified in the Boston Building Code.

Column Spacing:

Although radial column spacing would be determined to a large extent by structural demands, it was apparent that tangential column spacing could be varied within limits to optimize foundation design. Increasing the number of columns in the tangential direction would lessen the load carried by each column but too many columns would cause the intercolumn spacing to decrease to the point where each column would be affected by the loads of its neighbors.

It was discovered that eighty bays would be an optimal solution. Fewer bays would lighten the structure insignifigantly but would greatly increase the load on each column, while a greater number of bays would reduce the column spacing to the point of column-column interaction.

Cantilevered Roof:

Operating within this context, a preliminary design calling for a cantilevered roof over a portion of the upper deck was investigated. It was suggested that such a roof would serve to protect spectators while still allowing a open stadium. Extensive design to optimize such a roof in terms of cost and weight distribution showed that the benefits afforded in terms of spectator protection would still be overruled by cost

and weight criteria.

Reinforced Concrete Structure:

On this basis, that bay shown in fig. (G.1) was selected for the majority of the stadium, to be varied as seating requirements demanded, as in fig. (G.2) for the typical outfield bay. These sections would be designed both, in reinforced concrete as well as in steel.

All members, with the exception of the columns, are of precast reinforced concrete, the columns are cast in place. The design is a ballanced design and is based upon 150 psf. live load for the seating deck and 100 psf. live load for the interior floors. The sizes of members shown in fig. (G.1) and fig. (G.2) are tabulated in table (A).

It was found in the course of the concrete design that lateral loads on such a circular structure could be carried without the inclusion of radial beams by the design of a flooring system to act as a series of horizontal compression rings. With lateral stability so provided, no further account of wind loading would be taken. The eliminiation of radial beams, however, requires that the press boxes and box seats of the fourth floor be supported by member 29 and column 25 as shown in fig. (G.1).

Three types of interior flooring systems were considered: a reinforced, 2-way action, continuous and cast in place floor; a reinforced, 1-way action, precast panel floor; and a floor consisting of precast, prestressed hollow core panels with a two inch topping. In addition to providing lateral stability, it was decided that the floor should allow for radial differential settlement. The precast, prestressed hollow core panel floor meets the above requirements if the panels are radial and simply supported. It was found to be less expensive and signifigantly lighter than either of the other systems. In addition, because the floor panels are simply supported and because the loading is symmetrical in the tangential direction, no moment is transferred to the columns by the floor.

Those floors on the seating decks, however, would not be required to provide lateral support and were therefore designed of precast channels as shown in fig. (G.3) to facilitate the placement of seating.

Steel Structure:

The same bays considered in the reinforced concrete design, those shown in fig. (G.1) and fig. (G.2), were designed in steel, the only difference being in the addition of three radial beams per floor per bay, as is discussed below.

The design considered live loads of 100 psf. for interior floors and 150 psf. for seating decks, as specified by the building code. Member sizes so designed have been tabulated in table (B).

During the steel design, however, the possibility of providing lateral stability through the design of the floor system was not considered. Resistance to wind loads was therefore provided by means of radial beams, three per floor per bay (not shown in fig. (G.1) and fig. (G.2). The fourth floor press box and box seats are therefore supported by the cantilevered radial beams of the fourth floor.

A similar floor system, that is, one of precast, prestressed hollow core panels, was chosen for the steel structure on the basis of cost and weight considerations. These panels, however, are tangentially placed because by so doing, advantage is made of the support of the radial beams, thinner panels may be used because of the lesser spans.

The floors of the seating decks are similar to the interior floors, they are also of precast, prestressed hollow core panels. Such panels, tangentially placed, accomodate seating as well as the precast channels considered in the reinforced concrete design, neither offering an immediately apparent advantage.

Conclusions:

A comparison of the column loads, shown in table (C), and the costs, shown in table (D), leads one to the conclusion that, although the reinforced concrete

design is somewhat heavier, the expense of a steel structure is sufficiently greater than the expense of a reinforced concrete structure to recommend the latter.

Table (A)

Reinforced Concrete Member Sizes

Member	Size (ft)	Volume (ft^3)	Weight (Tons)
1	shown in fig...	918	55
2	1.5*2.75*27.5	113.5	6.8
3	1.5*2.75*27.5	113.5	6.8
4	1.5*2.75*27.5	113.5	6.8
5	1.5*2.75*27.5	113.5	6.8
6	1.5*2.75*27.5	113.5	6.8
7	1.5*2.75*27.5	113.5	6.8
8	2.5*2.75*25.1	173	10.4
9	2.5*2.75*25.1	173	10.4
10	2.5*2.75*25.1	173	10.4
11	2.5*2.75*25.1	173	10.4
12	2.5*2.75*25.1	173	10.4
13	2.5*2.75*25.1	173	10.4
14	1.0*2.75*22.8	62.7	3.76
15	1.0*2.75*22.8	62.7	3.76
16	1.0*2.75*22.8	62.7	3.76
17	1.0*2.75*22.8	62.7	3.76
18	1.0*2.75*22.8	62.7	3.76
19	1.0*2.75*22.8	62.7	3.76
20	1.0*2.75*20.4	56	3.36
21	1.5*3.5*32.4	170	10.2
22	1.5*5.7*51.5	440	26.4
23	1*1*16	16	1.20

Table (A) continued

Reinforced Concrete Member Sizes

Member	Size (ft)	Volume (ft^3)	Weight (Tons)
24	1.35*1.35*28	51	3.82
25	2*2*82	328	24.50
26	2.7*2.7*82	598	45.00
27	2*2*125	500	37.50
28	1*2.6*20.8	54.1	3.25

Table (B)

Steel Structure Member Sizes

Member	Length (ft)	Section selected
1	134.2	41x16 plate girder
2	27.5	18WF 55
3	27.5	18WF 55
4	27.5	18WF 55
5	27.5	18WF55
6 .	27.5	18WF55
7	27.5	18WF55
8	25.1	21WF76
9	25.1	21WF 76
10	25.1	21WF 76
11	25.1	21WF 76
12	25.1	21WF76
13	25.1	21WF 76
14	22.8	33WF118
15	22.8	18WF45
16	22.8	21WF 68
17	22.8	27WF 84
18	22.8	21WF68
19	22.8	21WF 68
20	20.4	24WF68
21	32.2	33WF118
22	51.5	33WF 220

Table (B) continued

Steel Structure Member Sizes

Member	Length (ft)	Section selected
23	16	14WF 61
24	16	14WF 111
25	16	14WF 264
26	16	14WF 202
27	16	14WF 211
28	20.8	16WF 40
a	20.8 -29.5	35WF 118
b	31	16WF 50
c	30	18WF 45
d	30	16WF 45
e	50	33WF 141

Table (C)

Column loads

Reinforced Concrete:

(Ra) dead load =	194.4 tons
(Ra) total =	397.0 tons
(Rb) dead load =	216.7 tons
(Rb) total =	430.3 tons
(Rc) dead load =	276.9 tons
(Rc) total =	558.9 tons
(Rd) dead load =	75.21 tons
(Rd) total =	150.42 tons
(Re) dead load =	39.95 tons
(Re) total =	74.70 tons

Steel Structure:

(Ra) dead load =	143.7 tons
(Ra) total =	370.3 tons
(Rb) dead load =	161.5 tons
(Rb) total =	476 tons
(Rc) dead load =	108.0 tons
(Rc) total =	307.6 tons
(Rd) dead load =	71.2 tons
(Rd) total =	187.5 tons
(Re) dead load =	33.9 tons
(Re) total =	88.7 tons

Table D

Structural Costs

Segment	Quantity	Cost lower	Cost upper
Structural Steel	14306.1×10^3 lb	$ 6.44×10^6	$ 7.87×10^6
Reinforced Concrete	13029 yd^3	$ 3.257×10^6	$ 4.56×10^6
Precast floor Panels	1328.8×10^3 ft^2	$ 7.30×10^6	$ 8.30×10^6
Walls	47.320×10^3 ft	$ $.567\times10^6$	$ $.710\times10^6$
Moveable Stands		$ $.800\times10^6$	$ 1.20×10^6
Seating	53000 (approx)	$ $.900\times10^6$	$ 1.30×10^6
Mechanical		$ 2.5×10^6	$ 3.5×10^6
Electrical		$ 3.5×10^6	$ 4x106
Grading and Paving		$ $.5\times10^6$	$ $.7\times10^6$
Miscellaneous		$ 1.3×10^6	$ 1.5×10^6
Total, Steel Structure		$ 23.81×10^6	$ 29.08×10^6
Total, Reinforced Concrete Structure		$ 20.624×10^6	$ 25.77×10^6

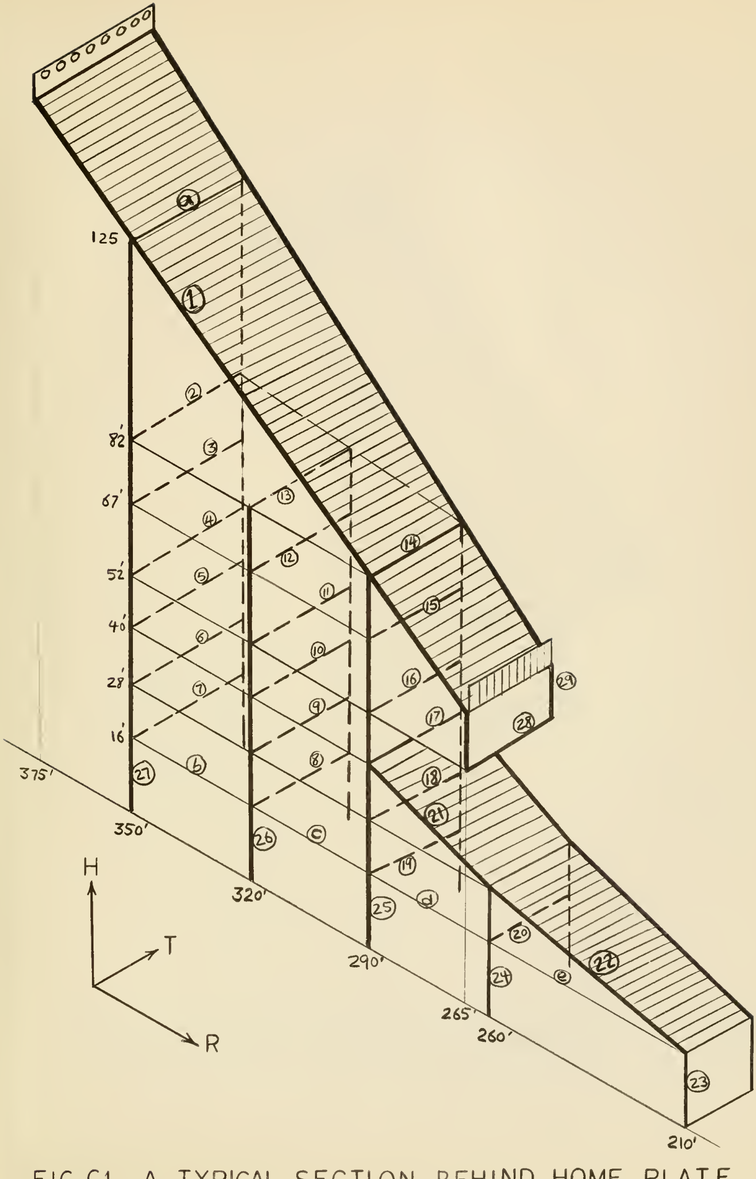


FIG. G1. A TYPICAL SECTION BEHIND HOME PLATE.

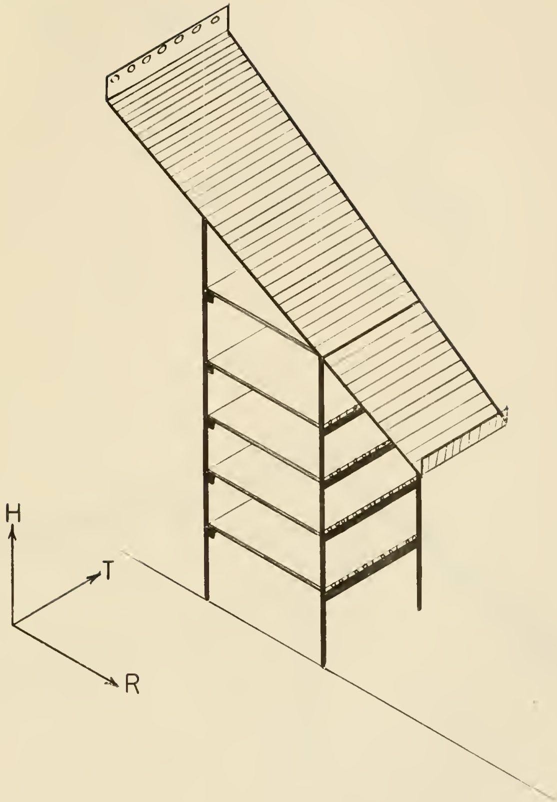
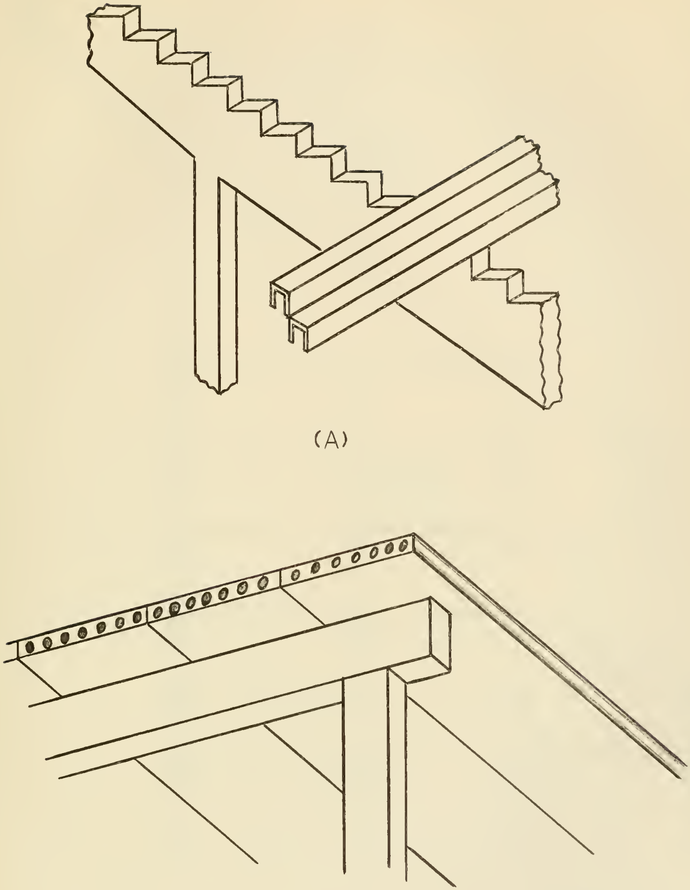


FIG. G2. A TYPICAL SECTION OF BASEBALL OUTFIELD



(A)

(B)

FIG. G3. (A) PRECAST CHANNELS FOR SEATING DECKS

(B) PRECAST, PRESTRESSED HOLLOW CORE PANELS.

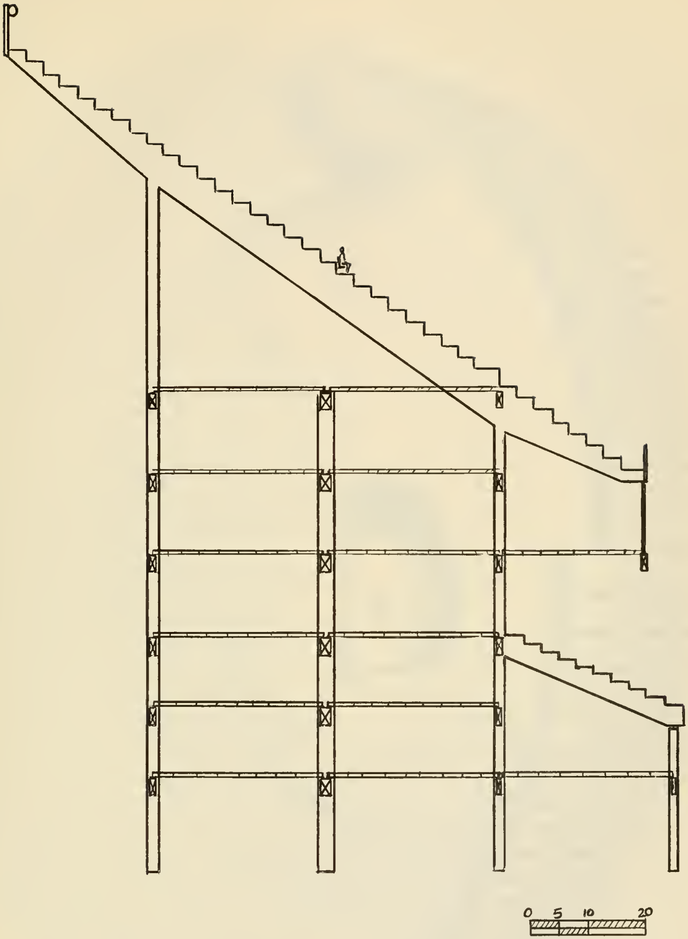
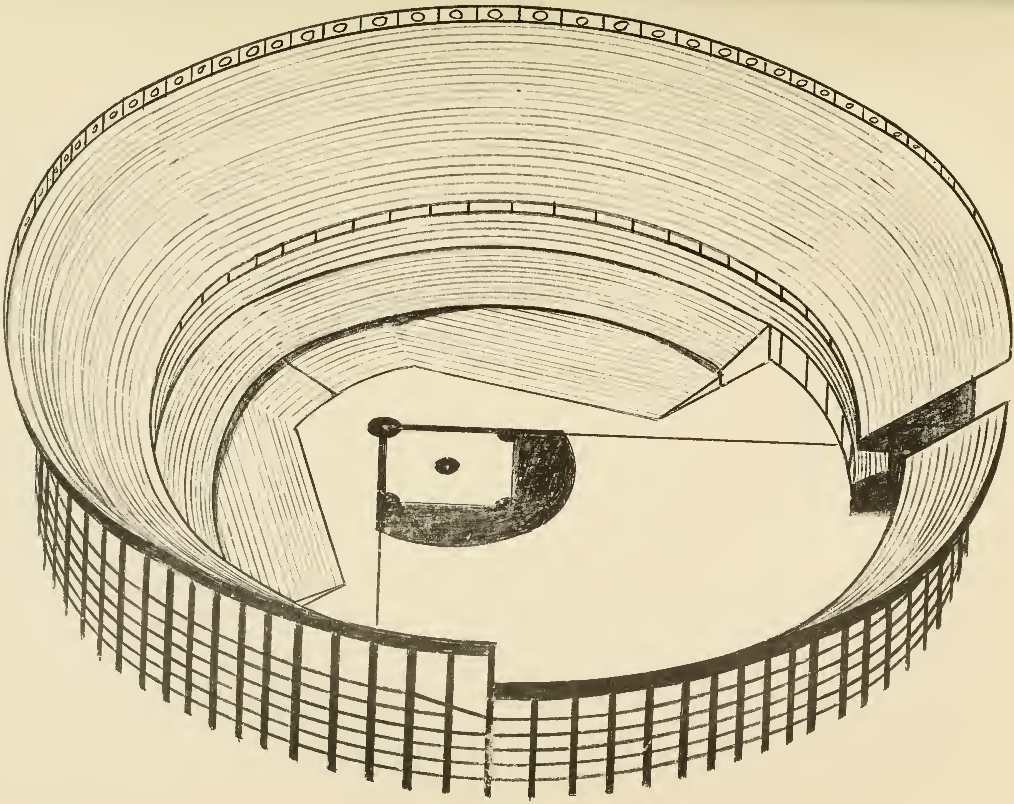


FIG. G4. A TYPICL CROSS SECTION.

ALL MEMBERS DRAWN TO SCALE.



ISOMETRIC DRAWING SHOWING THE PROPOSED STADIUM CONFIGURATION

APPENDIX H

STADIUM ROOF

ROOFING SCHEMES AND FEASIBILITIES

H.1 GENERAL. This appendix presents a brief look at the types of stadium roofing schemes that might be used, the approximate costs of some of these schemes, and our reasons for omitting a roof of any kind from the South Station stadium.

H.2 STRUCTURAL TYPES. Possible roof structures may be classified as one of four types:

(1) A roof which encloses the entire stadium and is fixed.
(2) A roof which encloses the entire stadium but part of which may be retracted, removed, or rotated
(3) A cantilever roof or partial covering
(4) No roof at all

Figure H.1 shows several examples of the first structural type. One of the most efficient and economical roof schemes used to cover long spans in structures is the spherical dome, which is primarily a direct thrust structure and behaves much like an arch. The supporting edge of the dome can be wound with tension rings, which take up horizontal thrusts and allow only vertical reactions to the supports. A steel frame Schwedler dome is shown in Figure H.1(a); an arch rib dome is shown in (b). Other dome systems include stiffened thin-shell concrete domes with spans of up to one thousand feet, lamella and lattice domes, geodesic domes, and wooden domes that span over eight hundred feet.

There are many other structural schemes that might be used to cover a stadium. These include the double cable system shown in (c), and ribbed frame surfaces, such as the monkey saddle and the hyperbolic paraboloid.

Figure H.2 shows three examples of the second structural type. The roof scheme sketched in (a) was proposed by the Greater Boston Stadium Authority. The fixed part of the roof consists of roof beams cantilevered toward the center of the stadium, leaving a 360 foot opening at the center. Supported on the fixed roof portion are twelve triangular sections which can be moved inward to convert the stadium to a completely enclosed structure. The scheme sketched in (b) was used on the Pittsburg Arena, which has a smaller diameter than that of the stadium. The roof consists of eight curved triangular sections, six of which can be rotated to overlap each other, thus uncovering the arena structure. The scheme shown in (c) consists of a ring of prestressed cables which support an inner removeable inflated plastic dome of 300 feet diameter.

Several stadiums built or planned in recent years have cantilevered roof structures which cover only a part of the stadium. (Figure H.3). The Washington, D. C., stadium has a seventy-two foot roof cantilever; the proposed Cincinnati stadium has a fifty-six foot roof cantilever. These cantilevers (a) are huge structural members weighing tens of tons. Similar to the pure cantilever is the roof scheme shown in (b), which is less expensive than the pure cantilever and covers all seats.

Finally, a stadium may have no roof structure at all. The cross-sections in Appendix F illustrate such a stadium structure.

H.3 ADVANTAGES, DISADVANTAGES, AND COSTS. A new stadium is now under construction in Philadelphia. Table H.1 lists 1968 cost estimates for four structural systems proposed for the stadium.

TABLE H.1
1968 COST ESTIMATES FOR THE
PHILADELPHIA STADIUM

	Structure	Cost(in millions)
1.	Basic Stadium Design	$33.0
2.	Basic Stadium Design with provision for future roof	34.0
3.	Fixed Dome Roof	52.8
4.	Roof with 400-foot diameter removable diaphragm	50.5

The fixed dome roof adds $20 million to the basic stadium cost, while the removable roofs adds almost $18 million to the basic cost. These additional costs are more than 50% of the basic stadium cost. The cost of the stadium with provision for a future roof is only slightly higher than the basic cost. However, the cost of any roof added at a later date is sure to cost much more than $20 million.

The fixed dome stadium has certain obvious advantages over an open stadium. First, the stadium is in essence an indoor arena. Every event could be held as scheduled with no delays or postponements due to rain or cold. Second, because of this certainty of all events being held, a rise in attendance would be expected, perhaps as much as 15% for baseball. The cost of the fixed dome is its greatest disadvantage. The cost is made up of the roof material itself, as well as the costs of a stronger structure and foundation, an increase of several million dollars in electrical and mechanical equipment, the cost of artificial turf, and the cost of better seating.

The retractable or removable roof schemes also have several obvious advantages over other roof schemes. Similar to the fixed dome, a retractable or movable roof insures that all events will proceed as scheduled. An advantage of the movable roof over the fixed roof is the smaller requirement for heating, ventilation, and air-conditioning. Also, the movable roof allows for baseball and footballl to be played in the open when the weather permits. In addition to the same disadvantages that pertain to the fixed roof, the movable roof is made expensive due to the elaborate mechanical systems that would be required to move the roof parts.

A cantilever roof is of course much smaller in area than either roof discussed above, and thus will cost much less in terms of materials and also will have a much less significant impact on structural and foundation costs. Furthermore, a cantilever roof does not involve elaborate electrical and mechanical systems. However, it is obvious that a cantilever roof cannot guarantee that every game will be played as scheduled nor can it provide protection from the elements for every spectator. Although a cantilever will add only several million dollars to the initial stadium cost, revenues may suffer because of the weather.

H.4 THE SOUTH STATION STADIUM ROOF SCHEME. In light of the above comments, the stadium proposed in this study does not include provision for a present or future roof of any type. Several important reasons leading to this decision follow:

(1) Settlement at the South Station site would be a serious problem for any structure built upon it. Either a fixed roof or movable roof scheme would significantly increase foundation loads

over and above those for a stadium with no roof. Furthermore, differential settlement will be magnified because these roof structures are supported by the outer edge of the stadium structure. Large differential settlements are bound to create serious problems within the stadium structure itself and especially with respect to the successful operation of any movable roof sections.

(2) A fixed or movable roof scheme will add millions of dollars to the cost of heating, ventilating, and air-conditioning.

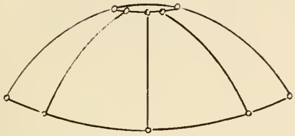
(3) The extra strength required to support a fixed or movable roof structure will increase the cost of the stadium structure and foundation.

These three points were sufficient cause for us not to consider either a movable or fixed roof scheme which would enclose the entire structure. The choice between a cantilever roof and no roof at all remained.

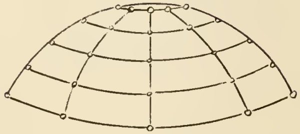
(4) For a cantilever roof to be effective in protecting spectators from the elements, it would have to be fairly large. A large cantilever would be expensive. Furthermore, events held in a stadium with a cantilever roof would still be held only at the mercy of the weather. Thus, the only real advantage of a cantilever roof over no roof at all is that it protects several more spectators from the elements. We felt that a stadium with no roof would provide essentially the same service as a stadium with a cantilever roof. Our decision was also directed by a desire to keep the cost of the stadium as low as possible. With the financial difficulty that Boston has had in getting a stadium

approved, we did not consider it worthwhile to even consider the possibility of providing for a future roof. In several years the cost of the roof will be as great as the cost of the stadium is today.

FIGURE H.1. FIXED ENCLOSING ROOFS

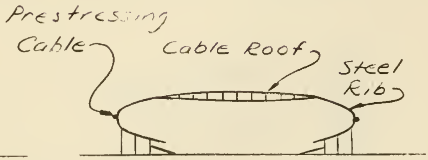


(b) ARCH RIB DOME



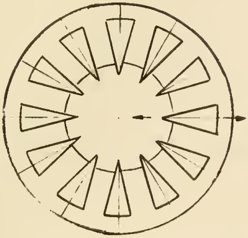
(a) SCHWEDLER DOME

(c) CABLE SUSPENDED ROOF

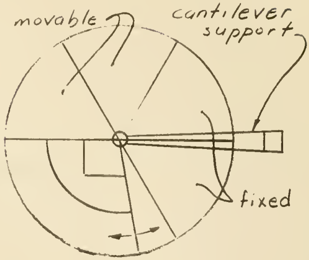


(d) CABLE & STEEL RIB ROOF

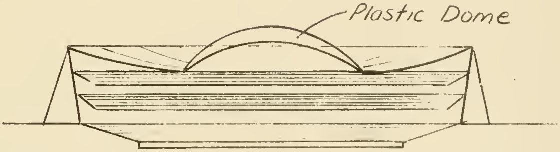
FIGURE H.2. REMOVABLE ENCLOSING ROOFS



(a) GBSA-SLIDING FINS

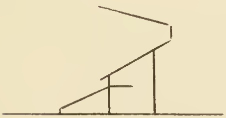


(b) ROTATING SECTORS

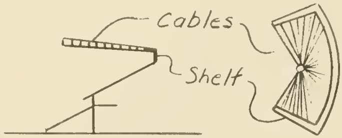


(c) REMOVABLE INFLATED PLASTIC DOME

FIGURE H.3. PARTIALLY ENCLOSING ROOFS



(a) CANTILEVER



(b) CABLE CANTILEVER

APPENDIX I

COSTS AND REVENUE ESTIMATE

CONSTRUCTION COSTS

The total construction costs which would be incurred from the project can be broken down into five major components. These are the stadium structure and facilities, the foundation, movement of the railroad tracks, pedestrian overpasses, and the on-site parking lot.

By far the largest of these costs is that of the structure and related facilities. Variance in this estimate will constitute the main variance of our total estimate and we have therefore considered a range of costs for this component.

The aggregate estimates themselves are as follows: (figures expressed in millions of dollars)

Structure and Facilities		22.248 - 27.140
Foundation		1.715
Track Relocation		.200
Pedestrian Overpasses		1.250
On-site parking		.037
	TOTAL	\$23.550m - \$30.342m

FINANCING AND DEBT SERVICE

A major component of annual operating expense for the stadium will be debt service. It is envisioned that through a bond issue by the Authority the construction will be financed. It is the annual interest and redemption cost of this bond which we wish to assess.

To keep this expense at a minimum, the Authority should issue as long a term bond as possible, which we will assume to be forty years. The other key variable is the interest rate of the issue, and this is difficult to estimate. This interest rate will depend on the prevailing conditions in the capital market at the time of issue and the perceived credit of the Authority.

The perceived credit of the Authority, that is how the market will assess the risk of investing in the bonds, will be determined primarily by what funds are pledged to insure the bonds. If the state of Massachusetts pledges its credit to back the bonds of the Authority, then the Authority's credit will be identical to the state's. Using Moody's Investment Service rating system this means the Authority will be able to issue grade Aa bonds, the present rating of Massachusetts' general obligations. Alternatively, if the state does not pledge its credit, the bonds must be insured by the Boston tax base or the Authority's operating revenue alone, the bond rating would almost surely fall in the Baa class, which is the rating of Boston's general obligations.

The current difference in the two bond ratings has been in the neighborhood of .6 percent, which will represent roughly 10 percent of the total interest expense. Whether or not this is a significant difference will be determined by our analysis of financial performance after construction costs have been estimated. It is true that

the unwillingness of the state to back the bonds in 1966 made the crucial difference in financial desirability.

The current averages of municipal bond rates tabulated at the beginning of this year was 5.25% for grade Baa and 4.6% for Aa. Currently these averages are much higher with a Baa revenue bond probably costing nearer 7 percent. The key problem, however, is to assess what these rates might be at the start of construction which will be postulated as the Spring of 1970.

Since interest rates are presently at the highest point in history, and credit is unlikely to become tighter, we will set 7 percent as a ceiling value on any revenue (Baa) bond which might be issued. It is unlikely, however, that interest rates could drop more than two percent and 5 percent is a reasonable bottom rate. Performing the financial analysis for this range of values should give a fair indication of the project's sensitivity to prevailing interest rates.

Using an interest and repayment schedule which allows for constant annual debt service over the life of the issue, we can calculate this annual cost over the range of both construction costs and interest rates. This is done in the Table below.

ANNUAL DEBT SERVICE

		Interest Rates		
		5%	6%	7%
CONSTRUCTION COST (millions)	23.450	$1.442m	$1.638m	$1.890m
	26.796	$1.644m	$1.868m	$2.106m
	30.342	$1.854m	$2.109m	$2.380m

OPERATING EXPENSES

The annual operating expenses for the new stadium will not be a greatly

varying item. Most expenses are fixed, with cleaning and maintenance the only component that varies significantly with usage levels. The estimates which are made in this area can be quite accurate.

The Stanford report has an itemization of expenses which is quite thorough, although their actual estimates are not wholly applicable to our stadium. Adjusting the Stanford estimates to our stadium, the projected annual operating expenses are as follows:

General Expenses		$260,000
Events Staff		46,000
Lighting		70,000
Cleaning and Maintenance		200.000
Repairs and Grounds Upkeep		92,000
Equipment Rental		81,000
Insurance		115,000
Contingincies		57,000
	TOTAL	$821,000

Variance in cleaning costs due to deviations from expected attendance might introduce a range of plus or minus $70,000 on these costs which does not seem to be large enough to consider in light of more significant uncertainties.

The reduction of these estimates over those of the Stanford report are related to the absence of a dome in our stadium design. This greatly reduces the costs of heating and air conditioning as well as reducing the costs of technical personnel necessary to maintain the air conditioning system. This itemized estimate matches very closely with that of the Mayor's Commission whose more

aggregate estimate yielded a total of $830,000.

MAJOR REVENUE SOURCES AND CONTRACT TERMS:

The major sources of operating revenue to the stadium will be rental, concession and parking.

Rental for the Red Sox could be 6% of the first $1 million of net receipts (gross sales minus a user charge) 10% of the next million, and 15% of everything thereafter. Rental from other sports occupents (football and soccer) should be a straight 10% of net receipts from ticket sales. The same rate should apply to entertainment events in the stadium. Non-commercial users of the stadium (religious meetings, charity gatherings,) could be charged a straight $2000 per day.

Concession terms with the Red Sox could be worked so as to avoid a cut in concession revenue to the Sox. The tenant and stadium should get a 30% cut of total concession revenue. The Red Sox share would be two-thirds of the $300,000 and one-half of everthing thereafter, For all other sports occupants, the 30% tenant-stadium cut above should be split evenly. For all other events, the stadium should get all of the 30% concession share.

Parking revenue will be generated by a 5400 space garage and a 3000 space on-site parking lot. A reasonable parking fee would be $2.00/car for any stadium event. Parking revenue need not be shared with the tenants. At present, there is virtually no parking revenue taken in by professional sports teams. Therefore, if denied a share of parking revenue, these teams will face no revenue loss.

RENTAL REVENUE SENSITIVITY TO ATTENDANCE LEVELS:

The following three tables estimate revenue from rental for three different

attendance levels. Table 1 is for the highest probable revenue from rental, Table II for the lowest, and Table III is for an intermediate report.

TABLE I

Event	Attendance	Net Average - Ticket Price	Net Recp't	Rent to Auth.
Baseball	2,000,000	$2.35	$4,700,000	$565,000
Football:				
Patriots	420,000	4.60	1,932,000	193,200
College	150,000	3.70	555,000	55,500
High School	80,000	1.00	80,000	8,000
NFL Exhibition	52,000	4.60	239,000	23,900
Soccer	60,000	2.35	141,000	14,100
Entertainment	143,000	2.35	336,000	33,600
Other Events	528,000	**	**	40,000
	3,741,000		Total rental revenue =	$933,300

* Under terms previously stated in this report
** On a daily rental basis.

TABLE II

Event	Attendance	Net Average - Ticket Price	Net Recp't	Rent to Authority*
Baseball	600,000	$2.35	$1,410,000	$101,000
Football:				
Patriots	300,000	4.60	1,380,000	138,000
Entertainment	25,000	2.35	58,600	5,860
Other Events	110,000	**	**	20,000
	1,035,000		Total rental revenue =	$264,860

(This lowest probable rental revenue figure was gotten by assuming that the Patriots are the sole football users and that pro soccer fails. In addition, attendance for the non-sports events was cut considerably from the rather optimistic estimates of Table I.)

TABLE III

Event	Attendance	Net Average - Ticket Prices	Net Recp't	Rent to Authority
Baseball	1,000,000	$2.35	$2,350,000	$212,500
Football:				
Patriots	350,000	4.60	1,610,000	161,000
College	50,000	3.70	185,000	18,500
NFL Exhibition	50,000	4.60	230,000	23,000
Entertainment	75,000	2.35	176,250	17,625
Other Events	200,000	**	**	24,000
	1,725,000		Total rental revenue	$456,625

Comparing tables I and II, it is seen that rental revenue is very sensitive to attendance levels. A drop of 2,706,000 in attendance caused a drop of $668,440 in rental revenue. In percentage terms, a 73% drop in attendance caused rental to go down 72%.

CONCESSION REVENUE SENSITIVITY TO ATTENDANCE LEVELS:

Tables IV - VI give estimates of revenue from concessions for the three attendance levels previously used. Table IV is for the highest probable revenue from concessions, Table V for the lowest, and Table VI for the intermediate point.

TABLE IV

Event	Attendance	Per capita expenditure	Total revenue	Share to Authority
Baseball	2,000,000	$1.00	$2,000,000	$250,000
Football				
Patriots	420,000	.80	336,000	50,400
College	150,000	.70	105,000	15,750
High school	80,000	.50	40,000	6,000
NFL Exhibition	52,000	.80	41,600	6,250
Soccer	60,000	.80	48,000	7,250
Entertainment	143,000	.60	85,800	25,700
Other events	528,000	.50	260,000	77,900
	3,741,000	Total Concession Rèvenues		$439,250

TABLE V

Event	Attendance	Per capita expenditure	Total revenue	Share to Authority
Baseball	600,000	$1.00	$600,000	$60,000
Football				
Patriots	300,000	.80	240,000	36,000
Entertainment	25,000	.60	15,000	4,500
Other events	110,000	.50	55,000	16,500
	1,035,000	Total Concession Revenues		$117,000

TABLE VI

Event	Attendance	Per capita expenditure	Total revenue	Share to Authority
Baseball	1,000,000	$1.00	$1,000,000	$100,000
Football				
Patriots	350,000	.80	280,000	42,000
College	50,000	.70	35,000	5,250
NFL Exhibition	50,000	.80	40,000	6,000
Entertainment	75,000	.60	45,000	13,500
Other events	200,000	.50	100,000	30,000
	1,725,000	Total Concession Revenues		$196,750

From Tables IV and V, it is clear that concession revenue is also very sensitive to attendance. A drop of 2,706,000 in attendance caused revenue to go down by $322,250. A drop of 73% in attendance caused a 73% drop in concession revenue to the Authority.

PARKING REVENUE SENSITIVITY TO ATTENDANCE LEVELS:

Parking revenue will be generated by a 5400-space garage and a 3000 space on-site lot. Parking revenue generated by stadium events alone will be estimated.

The expected number of persons per car, according to the Transportation Planning Department of the Boston Redevelopment Authority, is as follows:

Football:

Professional: 2.3 persons/car

College : 3.5 persons/car

Baseball:

day games : 1.5 persons/car

night games : 2.5 persons/car

The same agency estimates that 20% of the spectators at events in Fenway Park between 1961-63 used public transportation.

These BRA estimates will be used in calculating the parking revenue to the stadium authority from stadium events.

It will be assumed that the total of 8400 parking spaces will be close to 90% available on weekends, nights and holidays, and nearly 40% available otherwise.

A fee of $1.50 will be the cost of parking for any stadium event in the following revenue estimate.

From the above availability percentages, there should be about 7475 spaces available on nights, weekends, and holidays, and 3050 spaces available otherwise.

Table VII gives an estimate of highest problable parking revenue, Table VIII lowest probable, and Table IX the estimate for the intermediate attendance level.

From Tables VII and VIII it can be seen that a 73% drop in attendance causes parking revenue to drop by $1,025,050, or 63%. Parking is not quite as sensitive to attendance drops as rental and concessions revenue. However, it is still very sensitive.

The Mandatory Use Charge:

The revenue reaised by a use charge may be utilized in one of two ways. It could serve as another operating revenue source for the Authority. If the Authority faces no deficit in a given year, the revenue from the use charge could be allowed to accrue. Then in years when there is a net operating loss, the Authority could use the charge accruals to pay off the deficit. The use charge could also serve to enable the Authority to get the Commonwealth to guarantee its debt service in years of heavy deficit. The use charge in later, more prosperous years, would enable the Authority to make up to the taxpayers of the state any payments received as aid for debt service deficiencies. This state guarentee would also make the bonds issued by the authority more attractive to investors.

Tables X - XII show what would accrue from a user charge for the three attendance levels previously used. Estimates are for an annual accrual. Note the use charge ranges from 6% of average ticket prices for baseball to 8% for football[1]. There is no use charge levied on events which pay on a daily rental basis.

Table VII

Event	Attendance	Weekday Attend.	Other Attend.	Average no. of persons by car/game: weekday	Average no. of persons by car/game: other	Persons/car: weekday	Persons/car: other
Baseball	2,000,000	150,000	1,850,000	6325	25,200	1.5	2.5

No. of game dates: weekday	No. of game dates: other	Parking fee	Weekday revenue	Other revenue	Total baseball parking revenue
19	59	$1.50	$86,750	$66,000	$746,750

Football:	Attend.	No. of events	Aver attend. by car/event	Persons/car	Cars/event	Pkg. fee	Parking revenue
Patriots	420,000	7	48,000	2.5	19,200	$1.50	$ 78,500
College	150,000	3	40,000	3.5	10,900	1.50	33,600
High schl.	80,000	2	32,000	3.5	9,150	1.50	22,400
Exihibition	50,000	1	50,000	2.5	16,000	1.50	11,200
Soccer	60,000	10	4,800	2.5	1,920	1.50	28,800
Entertainment	143,000	6	19,100	2.5	7,650	1.50	67,250
Other events	528,000	20	21,200	2.5	8,450	1.50	224,000
	3,741,000						465,750

Baseball parking revenue:	$ 746,750
Other parking revenue:	465,750
Total parking revenue:	$1,212,500

Table VIII:

Event	Attendance	Weekday attend.	Other attend.	Average no. of persons by car/game weekday	Average no. of persons by car/game other	Persons/car weekday	Persons/car other
Baseball	600,000	42,500	557,500	1790	7700	1.5	2.5

No. of game dates weekday	No. of game dates other	Parking fee	Weekday revenue	Other revenue	Total baseball parking revenue
19	59	$1.50	$31,000	$272,000	$303,000

Football:	Attend.	No. of events	Aver. attend. by car/event	Persons/car	Cars/event	Pkg. fee	Parking revenue
Patriots	300,000	7	34,200	2.5	13,700	$1.50	$78,500
Entertainment	25,000	1	20,000	2.5	8,000	1.50	11,200
Other events	110,000	10	8,800	2.5	3,520	1.50	52,750
	1,035,000						$142,450

Baseball parking revenue:	$ 303,000
Other parking revenue:	142,450
Total parking revenue:	$ 445,450

Table IX:

Event	Attendance	Weekday attend.	Other attend.	Average no. of persons by car/game weekday	Average no. of persons by car/game other	Persons/car weekday	Persons/car other
Baseball	1,000,000	70,000	930,000	2960	12,600	1.5	2.5

No. of game dates weekday	No. of game dates other	Parking fee	Weekday revenue	Other revenue	Total baseball parking revenue
19	59	$1.50	$56,300	$438,000	$494,300

Football:	Attend.	No. of events	Aver. attend. by car/event	Persons/car	Cars/event	Pkg. fee	Parking revenue
Patriots	350,000	7	40,000	2.5	16,000	$1.50	$ 78,500
College	50,000	1	40,000	3.5	11,400	1.50	11,200
Exhibition	50,000	1	40,000	2.5	16,000	1.50	11,200
Entertainment	75,000	3	20,000	2.5	8,000	1.50	33,600
Other events	200,000	12	13,300	2.5	6,725	1.50	121,000
	1,725,000						$ 254,000

Baseball parking revenue:	$ 494,300
Other parking revenue:	254,000
Total parking revenue:	$ 748,300

TABLE X:

Event	Attendance	Average Use Charge	Use Charge Revenue
Baseball	2,000,000	$ .15	$ 300,000
Football			
Patriots	420,000	.40	168,000
College	150,000	.30	45,000
NFL Exhibition	52,000	.40	20,800
Soccer	60,000	.15	9,000
Entertainment	143,000	.15	21,450
	3,133,000		$ 564,250

TABLE XI:

Event	Attendance	Average Use Charge	Use Charge Revenue
Baseball	600,000	$ .15	$ 90,000
Football			
Patriots	300,000	.40	120,000
Entertainment	25,000	.15	3,750
	925,000		$213,750

TABLE XII:

Event	Attendance	Average Use Charge	Use Charge Revenue
Baseball	1,000,000	$ .15	$ 150,000
Football			
Patriots	350,000	.40	140,000
College	50,000	.30	15,000
NFL Exhibition	50,000	.40	20,000
Entertainment	75,000	.15	11,250
	1,525,000		$ 336,250

MISCELLANEOUS REVENUE AND THEIR SENSITIVITY TO ATTENDANCE LEVELS:

Other minor revenues will come from office and equipment rental, possibly a share of Red Sox television and radio rights, and rentals of scoreboard advertising to a major company. Of these three only the office and equipment rental is a certainty. Table XIII shows a highest and lowest probable estimate of miscellaneous revenues, and a figure for an intermediate point.

TABLE XIII

Source	Highest Revenue	Lowest Revenue	Intermediate Revenue
Office Rental	$40,000	$40,000	$40,000
Equipment Rental	10,000	10,000	10,000
TV and Radio	100,000	0	70,000
Scoreboard Advertising	100,000	0	0
Total Micellaneous Revenue	$250,000	$50,000	$120,000

TOTAL OPERATING REVENUE AND ITS SENSITIVITY TO ATTENDANCE LEVELS:

TABLE XIV

Source	Highest Probable	Lowest Probable	Intermediate Point
Attendance	3,741,000	1,035,000	1,725,000
Rental	$933,300	$264,860	$456,625
Concessions	493,250	117,000	196,750
Parking	1,212,500	445,450	756,000
Misc. Revenue	250,000	50,000	120,000
Total Op. Revenue	$2,835,050	$877,310	$1,529,375

Comparing highest and lowest probable attendance levels, it is seen that a loss of 2,706,000 in attendance brings a loss of $4,911,740 in total operating revenue. In percentage terms, a 73% drop in attendance causes total operating revenues to fall about 70%. This points up again how important high attendance levels are in keeping the stadium project on a sound financial footing. (NOTE: Contract terms in this report for rental and concessions are those proposed in the Stanford Research Report on the Proposed Greater Boston Sports Center.)

DERIVED TAX REVENUES:

It is certainly clear that the operation of a new stadium complex will generate indirect but real economic benefits for Massachusetts and Boston. The most apparent of these benefits are the tax revenues which will be derived from the stadium construction and operation. The estimated magnitude of these revenues is perhaps the single most important measure of the stadium's economic impact.

The most detailed analysis made with regards to these revenues is contained in the Stanford Research Institute's report. The Mayor's Stadium Commission recently released a similar analysis yielding considerably different figures. In analyzing the two reports we have tried to formulate an analysis which will yield significant and realistic measures. Neither Stanford nor the the Mayor's Commission has, in our opinion, done this. First, we will not attempt to duplicate the input-output analysis performed by Stanford. Their approach was to use this analysis to estimate all the spending in the economy which would be generated by construction spending and the spending of stadium attendees. Essentially this is an accounting of the economic "multiplier effect."

With indirect spending in different sectors of the economy estimated, appropriate tax revenues were estimated.

This procedure, while intuitively appealing, was discovered to include a number of inaccuracies making it of questionable value. The input-output data used showing spending relationships between different industries was complied by the Department of Commerce for the year 1958. A similar study has not been done more recently, and ten years of technology has certainly changed these relationships. Secondly, the indirect spending which such analysisestimates is not necessarily confined to Massachusetts. Since the data is for the nation it would include interstate commerce with regards to stadium spending.

An estimate of greater significance can be made if we limit the analysis only to the direct spending of stadium attendants. The approach here is to realize that stadium attendants will be making other expenditures related to the attendance from which tax revenues will be derived.

This was the approach taken by the Mayor's Commission, but their results are questionable. The primary fallacy in their analysis is the use of total estimated attendance figures. As the Stanford report points out the value of the new stadium will come from the incremental attendance which it produces. Even here, some of the spending attributable to this incremental attendance would have occurred anyway, but in some sense we can assign it to the new stadium.

Adjusting Stanford's figures to account for the lack of a dome, we obtain

an unexpected incremental attendance of 852,000. If we assume a range of 50 percent deviation about this, which is the range of our total attendance estimates, we can proceed to use this to generate a range of estimated out-of-stadium spending.

The amount of such spending per attendant is difficult to assess. The Mayor's Commission suggests a range of 10 to 15 dollars is reasonable based on the expenditures of Minneapolis and Cleveland, while Stanford Research Institute implies a figure of 14.65 in 1966 which in present dollars would be about 16.75. While time does not permit a complete reanalysis of these figures, we tend to favor the Stanford report as it is based on less aggregate and more extensive statistics. We will therefore assume spending per attendee to be approximately 16 dollars.

We break this spending into four groups as shown below:

	Expenditures	Tax Yield
Food and Beverages	$5.59	$0.28
Lodging	2.40	0.12
Gasoline-Travel	1.28	0.25
Retail Purchase	6.73	0.20
	$16.00	$0.85

This implies a range of derived tax revenues below:

High Attendance:

1,280,000 attendants x 0.85 dollars/attendant = $1,090,000

Low Attendance:

426,000 attendants x 0.85 dollars/attendant = $372,000

We believe that this range justly and conservatively represents the incremental tax revenue which Massachusetts might expect to gain through the operation of the new stadium.

APPENDIX J

FINANCIAL PERFORMANCE AND ECONOMIC EVALUATION

APPENDIX J

We wish to analyse the economics of the stadium project from two points of view. First, we wish to determine the financial feasibility of the project in terms of the real cash costs and revenues of the proposed authority. Secondly, we wish to investigate the overall economic desirability of the project in terms of all costs and benefits occurring from it.

Financial Performance

The financial feasibility of the stadium project will, of course, be directly dependent on the actual revenues and costs which the Authority ultimately realizes. As was pointed out in Appendix I, these are figures which are difficult to estimate precisely. For this reason, we will project financial performance for both pessimistic and optimistic estimates of costs and revenues as well as mean values.

Table I projects the annual financial operation using those costs and revenues directly accruing to the Stadium Authority. Since the Authority is not expected to own and operate the parking garage, only those parking revenues generated by on-site are included in Table I.

As is illustrated by these figures, the expected annual deficit is in the neighborhood of $1,595,000. To make the Authority financially feasible, this deficit must be met from some other cash resources. Two specific sources would be incremental parking revenue generated from the adjacent garage, and the possibility of a user charge being affixed to ticket prices.

A range of possible incremental parking revenues is calculated in Appendix I as $778,500 to $286,000. The range of the user charge was calculated as

$213,750 to $564,250. If these funds are used as an operating revenue of the Authority, the range of expected annual deficit can be reduced as below:

(Expressed in Thousands)

		Expected	Optimistic	Pessimistic
Annual Operating Deficit		$1,643	$207	$2,610
Incremental Garage Revenue		484	778	286
User Charge		389	564	214
	Net Deficit (Surplus)	$770	($1135)	$2110

As the tabulation indicates, it is likely that there would remain a net deficit in the neighborhood of $770,000. This would have to be met from the general funds of the Commonwealth of Boston.

It should be noted that during construction, no stadium revenues would accrue and therefore the annual deficit in these years would equal the debt service itself. We can conservatively estimate that the period of this construction would be three years, with an expected debt service of 1868 million dollars.

Economic Evaluation

To make a decision about the economic desirability of the undertaking, it is necessary to bring together as much as possible all costs and benefits which are associated with the project. The preceding section evaluated the real cash flows which would be realized by the stadium operator. But clearly, the impact of the project is much broader than this.

A list of the economic benefits which the stadium would produce includes:

1. Tax revenue from stadium related spending of patrons;

2. Tax revenues from indirect spending generated by stadium operation;

3. Tax revenue from spending generated by stadium construction;

4. Direct economic benefits of major sports teams (assuming stadium decreases the likelihood of their leaving);

5. Indirect economic benefits of major sports teams - adding prestige which attracts both industry and labor;

(One and two above refer only to those revenues expected above those presently generated by Fenway Park). As was discussed in Appendix H, the only benefit in the above list which can be estimated quantitatively with any degree of significance is the tax revenues derived from the stadium-related spending (Item 1).

The major indirect cost of the stadium would be the traffic congestion it would produce in the South Station area. With this problem comes the possibility that this station site might require future investment in traffic improvement, as discussed in Appendix B.

The derived tax benefits have been estimated in Appendix I to lie between $1,090,000 and $372,000. A mean value of $732,000 is seen to defray the expected operating deficit by about $12,000 after the user charge and garage revenue are applied. However, it is clear that deviation in one of many estimates might be sufficient to make this tax revenue appear inadequate.

As has been noted before the annual deficit will ultimately be a function of attendance, rental and concession contract terms, parking revenues, the construction costs, the interest rate, the user tax, and operating costs. It is difficult to estimate these parameters precisely. Moreover, it is impossible to estimate numerically all economic benefits of the project.

Because of these problems, justification of the project through analysis of derived tax revenues and expected operating deficits seems in this case unrealistic. Rather, this analysis demonstrates that the proposed stadium cannot be overwhelmingly accepted or rejected in terms of quantifiable economic estimates.

The only basic conclusion that we can then reach is that the proposed stadium is financially feasible if the Commonwealth is willing to pledge in the neighborhood of $770,000 annually to the stadium's operation and accept the possibility of significantly greater annual requirements. For reasonable ranges of costs and revenues much of the deficit could be charged against tax revenues which the stadium-operation would generate.

However, the final decision must be made with consideration of all economic benefits here outlined and with a view of the significant traffic problems which would result. It has been the purpose of this analysis to specify and present those economic factors which are measurable in order to provide the decision-maker with the most precise data possible.

TABLE I

Projected Financial Performance
(thousands of dollars)

COSTS	Expected	Optimistic	Pessimistic
Debt Service	1,868	1,442	2,380
Operating Expense	821	821	821
TOTAL	2,689	2,263	3,201
REVENUE			
Rental	457	933	265
Concession	197	439	117
Parking	272	434	159
Miscelaneous	120	250	50
TOTAL	1,046	2,056	591
ANNUAL DEFICIT	1,643	207	2,610

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